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THESIS

DEVELOPMENT OF THE
A-6E/A-6E TRAM/KA-6D NATOPS
CALCULATOR AIDED PERFORMANCE
PLANNING SYSTEM (NCAPPS)

by

Douglas Francis Hargrave

December 1983

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The performance data contained in the Naval Air Training and Operating Procedures Standardization (NATOPS) Manuals for Naval aircraft are presented primarily in graphical form. Interpretation of these graphical charts is time consuming and susceptable to error.

By using multiple regression analysis and other curve fitting techniques the graphical charts can be modeled with

closed-form analytical equations. These equations can then be used in computer programs which perform the same functions as the original charts but with greater accuracy, speed and simplicity

This thesis conducts the above analysis on some of the more commonly used NATOPS performance data for the A-6 aircraft model. The result is the A-6E/A-6E TRAM/KA-6D NATOPS Calculator Aided Performance Planning System (NCAPPS) which is a library of A-6 performance software developed for the Hewlett-Packard HP-41CV hand-held programmable calculator. Procedures for developing the analytical models are described and a user's manual documenting the system is included.

Development of the A-6E/A-6E TRAM/KA-6D NATOPS Calculator Aided Performance Planning System (NCAPPS)

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This thesis conducts the above analysis on some of the more commonly used NATOPS performance data for the A-6 aircraft model. The result is the A-6E/A-6E TRAM/KA-6D NATOPS Calculator Aided Performance Planning System (NCAPPS) which is a library of A-6 performance software developed for the Hewlett-Packard HP-41CV hand-held programmable calculator. Procedures for developing the analytical models are described and a user's manual documenting the system is included.

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I. INTRODUCTION

The use of the extensive performance data contained in the Naval Air Training and Operating Procedures Standardization (NATOPS) manual is essential for the safe and effective operation of Naval aircraft. This information, much of it in the form of graphical charts, should be consulted both for mission planning as well as during certain inflight evolutions. Unfortunately, the complexity of these charts has resulted in a reluctance on the part of crewmembers to refer to them with regularity. As documented by both Siegel [Ref. 1] and Restivo [Ref. 2] in separate studies, their interpretation and use is time consuming, extremely error prone and totally impractical in the flight environment. As a consequence, most squadrons have resorted to "preplanned" mission data in the form of kneeboard cards containing performance data for several common configurations and missions. Often, the performance data used in mission planning is based on prior experience or habit and passed along via word-of-mouth. The annual NATOPS check may be the only time a crewmember actually gets "back into the book".

An obvious solution to this problem is to computerize the NATOPS charts and tables. Such a system would quickly and accurately provide operating and mission planning

performance data based on configuration and flight regime parameters input by the user. In addition to increased accuracy, the speed afforded by an automated system would give planners more flexibility, permitting the substitution of different mission parameters until an optimum profile or configuration is found. Finally, the system would promote the regular use of NATOPS data by flight crews, resulting in safer and more efficient use of the aircraft and its weapon systems.

Previous efforts [Refs. 1 and 2] have demonstrated the feasability of developing analytical models which accurately describe the graphical curves found in NATOPS. Two recent studies conducted at the Naval Postgraduate School by Campbell and Champney [Ref. 3] and Ferrell [Ref. 4] resulted in a series of performance programs written for the HP-41CV hand-held programmable calculator. Sponsored by the Naval Air Development Center, they were directed toward developing a Flight Performance Advisory System (FPAS) for several tactical Navy aircraft. The propose of FPAS was to provide flight crews with timely flight profile information which would result in the most efficient use of fuel. Although the objective of FPAS was energy conservation, the programs were also useful as general purpose planning and operating aids.

This thesis was prepared in response to a letter received from a West Coast A-6 squadron in early 1983

suggesting computerization of the A-6 NATOPS performance curves. Its purpose is to develop and document a series of programs based on the most important and commonly used A-6E/A-6E TRAM/KA-6D [Refs. 5 and 6] performance charts. The A-6E/A-6E TRAM/KA-6D NATOPS Calculator Aided Performance Planning System (NCAPPS) utilizes the HP-41CV calculator and is intended to be a nucleus of programs which, if proven to be useful, can be expanded to include additional NATOPS and Tactical Manual charts. The concepts initiated by Siegel and Restivo and refined by the FPAS programs form the foundation for this effort.

II. DISCUSSION

A. PROBLEM DEFINITION AND OBJECTIVES

The problem of developing a computerized NATOPS performance planning system was partitioned into four major areas.

1. Modeling the System

For each program, analytical models of the corresponding NATOPS curves suitable for program coding had to be found. Closed-form equations which describe the output variable in terms of one or more independent variables can be developed from regression analysis or curve fitting. Another method is to store a table of known results and use an interpolation routine to refine the output.

It was decided at the outset that, since NATOPS is the officially sanctioned source of performance data, the programs must be designed to conform exactly to the published NATOPS curves. No attempt would be made to refine or reevaluate the existing data.

The order of accuracy should be at least as good as the NATOPS charts. This is normally no better than about two percent but varies somewhat from case to case. In general, to provide acceptable accuracy the following tolerances were established:

Airspeed: within 2 knots or 2 percent, whichever is greater

Altitude: within 100 feet

Weight: within 100 pounds

Time: within 1 minute

Fuel flow: within 50 pounds per hour

Distance: within 2 nautical miles

The above tolerances are valid only over the range of values that the independent variables assume in the NATOPS charts. Extrapolation beyond these limits is not permitted.

2. <u>Selection of Hardware</u>

Once the performance data has been modeled it can be adapted to almost any computing system. The most important criteria for selection of an appropriate device are:

a. Portability

The device should be completely portable and self-contained so that it is suited for both pre-flight and in-flight operation.

b. Simplicity

The device should be relatively simple to operate and require little training to become proficient in its use.

c. Memory

Sufficient memory should be available to permit either direct storage of the programs or their timely access from a mass storage device.

d. Interactive displays

The device should be capable of displaying interactive ques to the user. Program output should be in a clearly readable alphanumeric format.

Additional desireable features are low cost, durability and maintainability.

3. Software

Once the performance data has been modeled and a specific computing device selected, the system software can be developed. Simplicity of operation, consistency of input/output procedures and accuracy should be the foremost considerations.

4. Documentation

A user's manual which fully documents the performance planning system must be developed. It should include detailed user instructions which explain the purpose of each program and the required inputs. The units used for the inputs and outputs should be defined along with any special features or program limitations. An example problem should be presented showing exact user procedures. Documentation should also include listings of the program codes, flowcharts and all equations used. The variables used in the equations along with their units should be defined. Finally, for calculator programs, program size and the usage of data storage registers and program flags should be given.

B. PROBLEM RESOLUTION

1. Multiple Regression Analysis

Most of the performance charts found in the NATOPS Manual require the user to traverse several subcharts using known values of various independent variables and moving sequentially from chart to chart until the desired performance variable is obtained. A typical example is the chart for Maximum Refusal Speed (Figure 1) which contains five subcharts relating six independent variables. For each subchart analytical forms of the two-dimensional curves are easily obtained but a difficulty arises because of the presence of a third variable. For example, in the Refusal Speed chart the baseline value for gross weight is a function of two other variables; the pressure altitude output baseline and runway length. An entire family of curves exists for various runway lengths, each curve having a different slope and position. Siegel [Ref. 1] approached this problem by fitting a collocating polynomial to the third variable curves (i.e. runway length), then developing an additional polynomial which predicted the coefficients of the first based on the behavior of the variable in question. In this way the whole family of curves could be modeled allowing interpolation (but not extrapolation) between the curves. Campbell and Champney [Ref. 3] approached the problem in a somewhat different manner using multiple regression

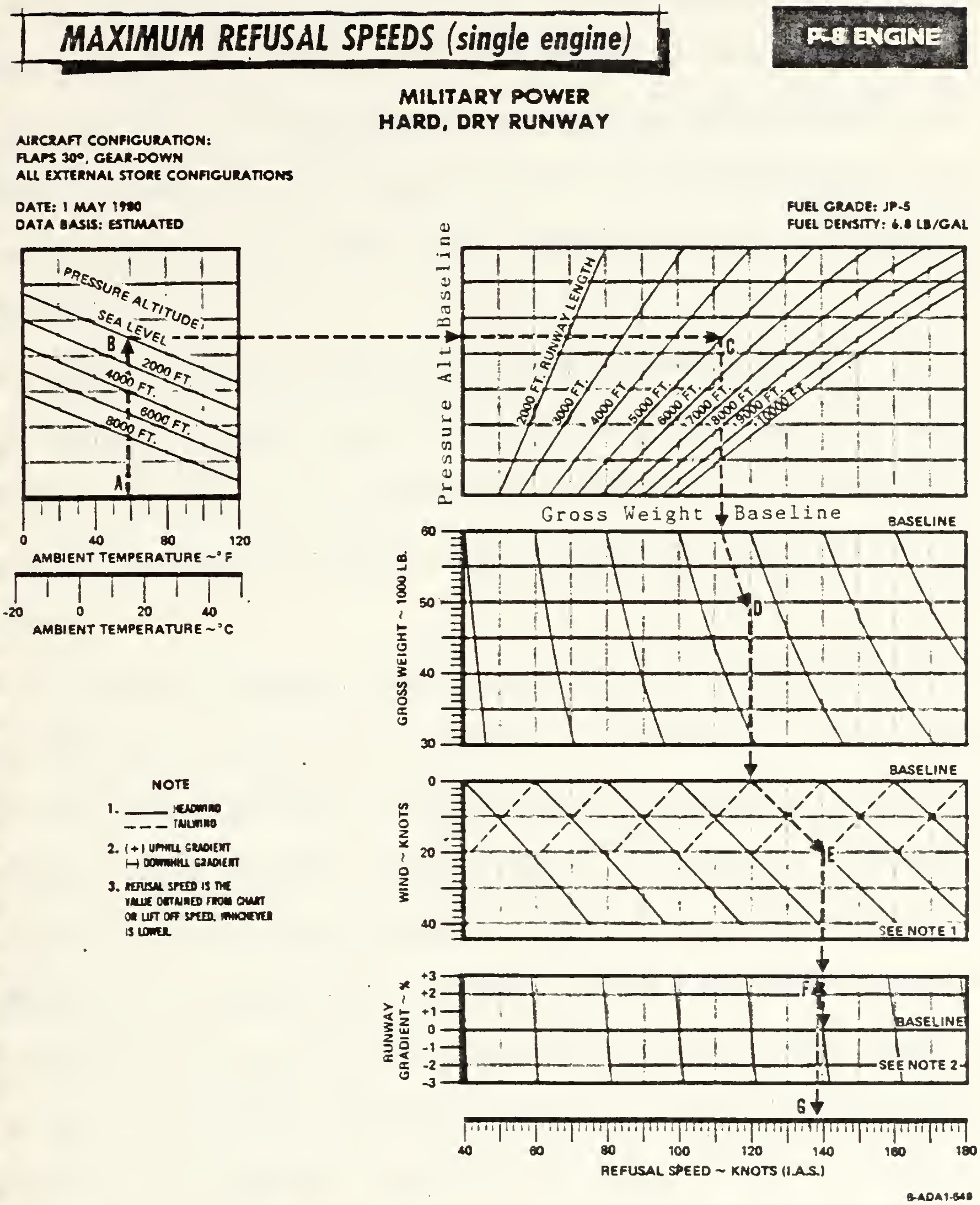

Figure 11-11 Maximum Refusal Speed (Single Engine)

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Figure 1 - Maximum Refusal Speed

analysis. In a given chart each of the independent variables are strongly correlated with the dependent variable. If data points are taken over the range of values assumed by each variable, a multidimensional hyperplane can be fitted between the points. The equation of this hyperplane represents a predictive analytical expression for the dependent variable.

Experimentation with each of the above methods led to the choice of the latter due to the excellent software available for multiple regression analysis, the superior accuracy achieved and the relative ease of completing the analysis.

Although a single linear equation can be developed using multiple regression analysis, it normally fails to describe the dependent variable with the degree of accuracy required in the present applicaton. A two-step procedure was used to solve this problem. First the number of independent variables was reduced to no more than three. This was done by splitting the analysis into more than one step, ultimately obtaining several coupled regression equations. The second step was to transform the independent variables so that they are represented as powers, cross-products or exponentials prior to completing the regression analysis.

Arriving at a final set of analytical equations using regression analysis was an iterative process which consisted of the following steps.

a. The NATOPS chart was subdivided into subsections containing three or fewer independent variables.

b. Data were obtained from the NATOPS chart. Sufficient data points were taken so that the full range of each variable was represented. To achieve acceptable accuracy this typically required three to five values for each variable. As an example, five values of each of three independent variables would result in 5 x 5 x 5 = 125 data points.

c. A transformation of the independent variables was chosen which achieved the required order of accuracy. In this analysis first and second degree cross products and second and third powers of the type AB, A^2B, A^2, A^3 were sufficient. Occasionally an exponential transformation of the dependent variable of the form y = exp[f(A,B,C)] had to be made.

d. A computer multiple regression analysis was performed on the first degree and transformed variables. The P-series of the Biomedical Computer Programs package [Ref. 7] developed at the University of California contains a routine (P9R) which selects the best subset of regression variables from a large group of independent variables. It also has an option within the program which makes the

required variable transformations. The best subset is the one with the highest multiple coefficient of determination R^2. This is the ratio of the variation explained by the multiple regression equation to the total variation of the dependent variable [Ref. 8]. For the present application R^2 had to closely approach unity to achieve the required accuracy.

e. Extraneous variables were eliminated. This was the interactive part of the process normally requiring three or four computer runs in which linearly dependent and redundant variables were culled. The object was to get the highest possible R with the fewest variables. Experience showed that, in general, an R^2 greater than 0.993 was needed to comply with the desired tolerances.

f. The final equation was tested. A program stub was written in which each equation was verified both for the original data as well as new intermediate data points. When all the regression equations for a given chart had been obtained and verified, they were combined into a single progrem which was rechecked using the same procedure. If the required tolerances were not achieved, the equations were refined furthur by adding additional transformations or trying an exponential transformation of the dependent variable. It is interesting to note that adding new data points did not improve the results but rather tended to degrade them furthur.

2. Hardware

The Hewlett-Packard HP-41CV programmable calculator (Figure 2) was selected as the computing device to be used for NCAPPS. With over 2000 bytes of program memory it is capable of handling relatively large and complex programs containing hundreds of instructions. It is fully portable, battery powered and its memory can be augmented with magnetic cards, digital tapes or memory modules. It is also capable of receiving and displaying alphanumeric information. Its operation is similar to many hand-held calculators, resulting in a minimum amount of user training. [Ref. 9] Lastly, it was successfully used with the FPAS programs which were similar in many ways to NCAPPS. Its major deficiency appears to be a susceptability to large fluxes of electromagnetic energy. During inflight trials of the E-2C FPAS the calculator failed when the aircraft's radar was turned on [Ref. 4]. This may not occur in the A-6 aircraft due to the different radar type and the forward directed main lobe but still remains an area for furthur investigation. The installation of a suitable RF shield would preclude this occurance in either aircraft.

3. NCAPPS

The following eight programs, representing some of the most commonly used NATOPS performance planning data, were written as the initial NCAPPS library.

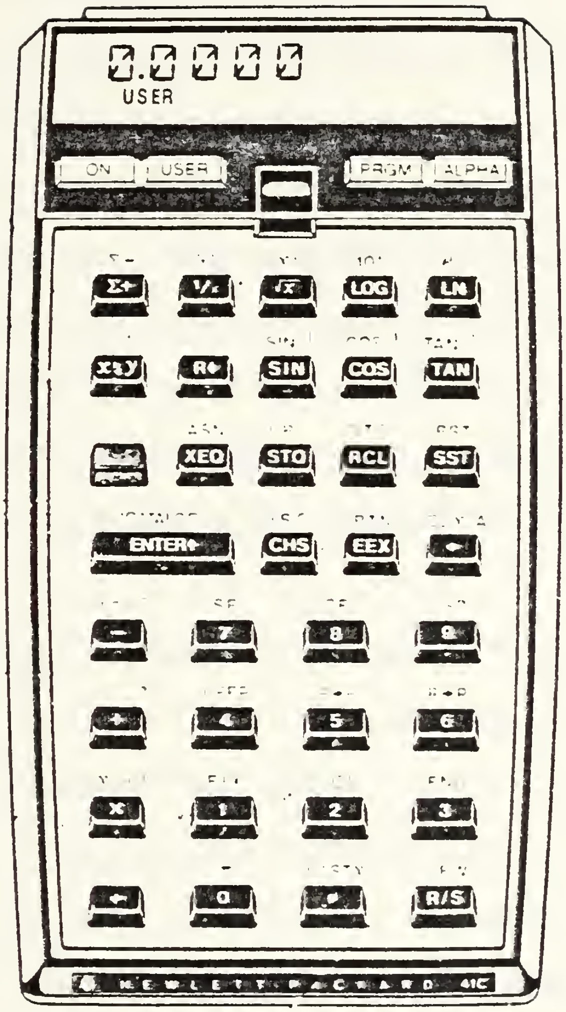

Figure 2 - Hewlett-Packard HP-41CV Calculator

a. Asymetric external store loading.

b. Maximum range climb, cruise and descent profile.

c. Drag count and external stores weight.

d. Landing and approach speeds.

e. Maximum refusal speed (single engine).

f. Tanker mission profile - KA-6D.

g. Normal take-off distance and line speed check.

h. Crosswind take-off/landing.

The NCAPPS programs were written to be user friendly and simple to operate. Once loaded and executed they are fully interactive, providing alphanumeric prompts to the user who is required only to enter numeric data, activate one of several user defined keys, or depress the {R/S} (RUN/STOP) key to proceed with program execution after a halt.

Each program was verified for stability as well as compliance with the previously stated tolerances across the range of the independent variables. This range is the same as that found in the original NATOPS chart and usually covers every reasonable operational situation. It is re-emphasized that the behavior of the governing equations as well as the aircraft itself is unknown beyond these limits and under no circumstances should extrapolation be attempted.

The programs vary in size from less than 50 to nearly 800 program steps. The larger programs occupy nearly all

of program memory precluding the loading of additional programs. This necessitates the use of an auxiliary program storage device in order to make the system practical. Although the programs can be read into memory from magnetic cards, this is normally time consuming and inconvenient. However, by storing all the software on an HP 82161A Digital Cassette Drive, any program can be loaded into main memory in less than thiry seconds. A furthur possibility exists for the creation of one or more plug-in read-only-memory (ROM) modules which contain the NCAPPS software. These modules can be developed by the Hewlett-Packard company on request.

Some of the NCAPPS routines were modeled after the earlier FPAS programs. This includes the general structure of the Crosswind Take-off/Landing program (XWL) [Ref. 4], and portions of the Climb, Cruise and Descent program (CCD) [Ref. 3].

4. User's Manual

A user's manual (Appendix A) was written which fully documents the NCAPPS programs. It consists of a user procedures section which contains program descriptions, user instructions and example problems followed by an appendix which provides more detailed documentaion such as flow charts, program listings and governing equations. The user procedures section is the most important part of the manual and contains the primary information needed to operate the

system. The appendix contains mostly supplemental documentation. It is expected that the HP-41CV Owner's Handbook [Ref. 9] will be used as a companion publication.

D. EXAMPLE CURVE ANALYSIS

The following example is presented to illustrate the procedure used to obtain an analytical equation for a graphically represented NATOPS performance curve. An equation will be developed which describes a portion of the NATOPS Normal Take-off Distance and Line Speed Check chart (Figure 3),[Ref. 5].

1. The main chart consists of five subcharts, each containing three variables. Each subchart was analyzed separately in accordance with the criterion stated above. The second subchart from the top which incorporates the runway temperature was chosen for this illustration. The dependent variable is the baseline value K_a which is the entering value for the altitude subchart below. The baseline value represents the horizontal axis which, for this analysis, was arbitrarily set from zero to fourteen corresponding to the vertical grid lines. The independent variables are the baseline value K_t received from the preceding subchart and the temperature in degrees Fahrenheit (T).

2. Data were manually recorded from the subchart (Fig. 4). Noting that eight guide curves are plotted on the graph, the altitude baseline value K_a was recorded for each

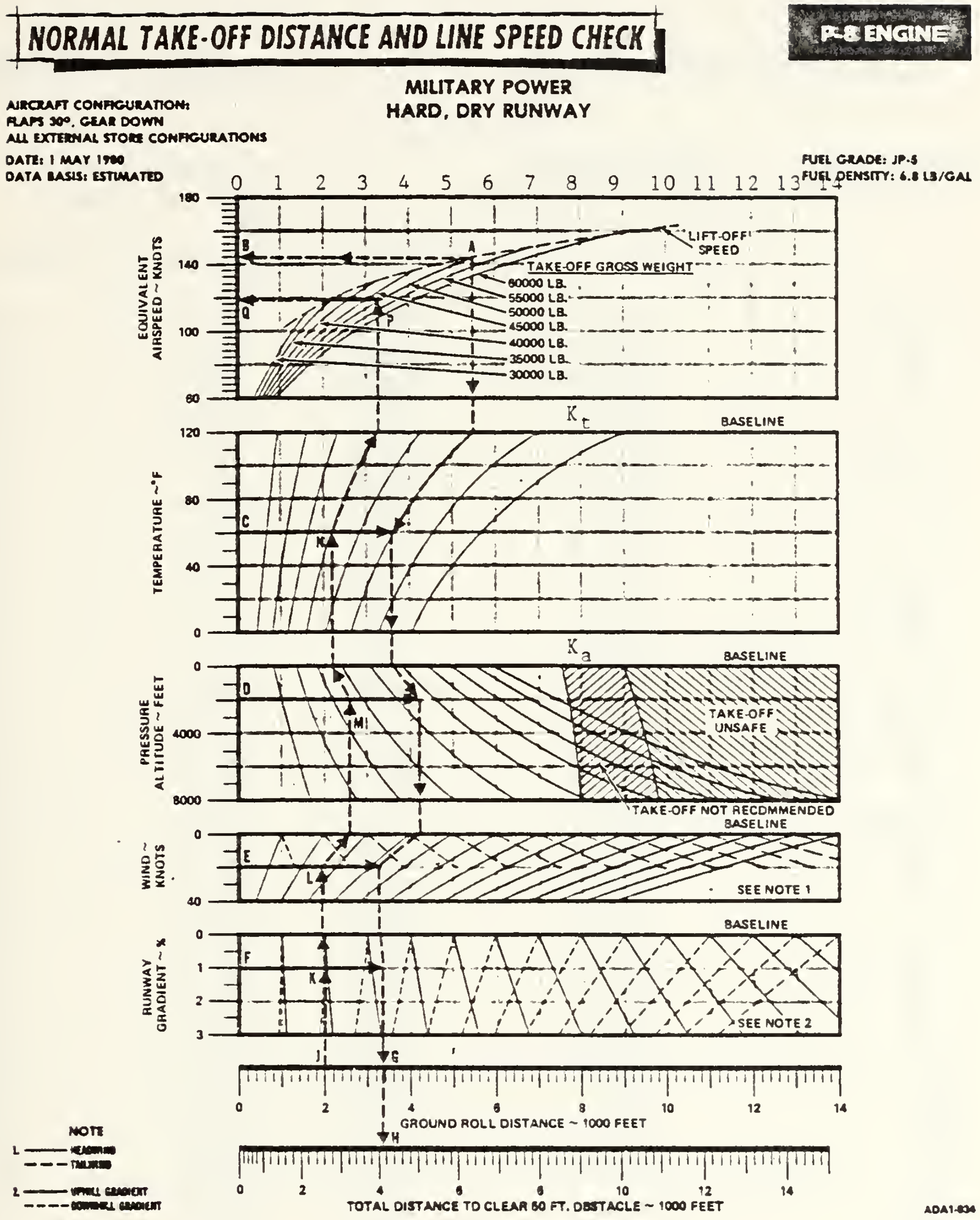

Figure 11-12 Normal Takeoff Distance and Line Speed Check

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Figure 3 - Normal Take-off Distance and Line Speed Check

DEPENDENT VARIABLE			INDEPENDENT VARIABLES	
Altitude Baseline (K_a)			Temperature Baseline (K_t)	Temperature (T)
From chart	Predicted	Error		
0.95	0.93	0.02	0.95	120
0.75	0.80	0.05	0.95	80
0.60	0.63	0.03	0.95	40
0.40	0.43	0.03	0.95	0
1.60	1.57	0.03	1.60	120
1.30	1.27	0.03	1.60	80
1.03	1.00	0.03	1.60	40
0.80	0.77	0.03	1.60	0
2.30	2.27	0.03	2.30	120
1.80	1.79	0.01	2.30	80
1.40	1.41	0.01	2.30	40
1.20	1.13	0.07	2.30	0
3.30	3.27	0.03	3.30	120
2.50	2.53	0.03	3.30	80
1.95	1.98	0.03	3.30	40
1.60	1.63	0.03	3.30	0
4.25	4.23	0.02	4.25	120
3.25	3.23	0.02	4.25	80
2.50	2.52	0.02	4.25	40
2.05	2.10	0.05	4.25	0
5.50	5.50	0.00	5.50	120
4.20	4.15	0.05	5.50	80
3.25	3.21	0.04	5.50	40
2.65	2.68	0.03	5.50	0
7.00	7.01	0.01	7.00	120
5.20	5.22	0.02	7.00	80
4.05	3.99	0.06	7.00	40
3.30	3.32	0.02	7.00	0
9.00	8.98	0.02	9.00	120
6.50	6.59	0.09	9.00	80
5.00	4.94	0.06	9.00	40
4.10	4.05	0.05	9.00	0

Figure 4 - Normal Take-off Distance and Line Speed Check Subchart 2 Regression Data

of the eight corresponding values of K_t and four evenly spaced temperatures (0, 40, 80 and 120). Thus 4 x 8 = 32 data points were obtained.

3. A transformation of the independent variables was developed for the initial computer analysis. It was anticipated that some of the initial transformed variables and possibly an untransformed variable would be eliminated at this step with additional refinements to be made in later runs if necessary. The initial independent variables chosen for this example were K_t, T, TK_t, T^2K_t, TK_t^2, T^2, K_t^2, T^3, K_t^3.

4. The computer analysis was completed using BIMED P9R (CP option) which performs a multiple regression analysis and selects those five subsets of regression coefficients which have the lowest Mallows' C_p. Mallows' C_p is defined as [Ref. 7]:

$$C_p = RSS/s^2 - (N - 2p')$$

where

RSS	is the residual sum of squares for the best subset being tested.
p'	is the number of variables in the subset (including the intercept).
s^2	is the residual mean square based on the regression using all independent variables.
N	is the number of cases.

The residual is the difference between the observed and predicted value of the dependent variable.

5. On the first run the variables TK_t, K_t^2 and T^3 were eliminated. The best subset, which had six independent variables, had an R^2 of 0.99970 and a Mallows' C_p of 7.38. The regression equation obtained was

$$K_a = 0.523991K_t + 0.00524248T + 3.024x10^{-5}T^2K_t + 9.50674x10^{-5}TK_t^2 - 3.81333x10^{-5}T^2 - 8.17348x10^{-4}K_t^3 - 0.0673642.$$

Due to the high coefficient of multiple determination no furthur runs were indicated for this case.

6. To test the results a program stub was written for the HP-41 which calculated the value of the dependent variable K_a predicted by the above equation. In Figure 4, regressed values of K_a obtained from the subchart are compared to those predicted by the equation. Figure 5 provides the same comparison for ten randomly selected points not used in the regression analysis. The average absolute error of K_a was 0.03 with a maximum error of 0.09. However, it is emphasized that the last significant digit shown for the manually obtained K_a is quite uncertain. In practice it was found that the regressed equation provided stability to the curves and tended to correct errors which appeared to be due to slight misalignments of the printed grid lines. For the five subcharts contained in the entire Take-off Distance and Line Speed Check chart an overall baseline error of 0.075 was estimated. This equates to 75 feet of ground roll which is well within the level of accuracy desired.

DEPENDENT VARIABLE			INDEPENDENT VARIABLES	
Altitude Baseline (K_a)			Temperature Baseline (K_t)	Temperature (T)
From Chart	Predicted	Error		
0.85	0.87	0.02	0.95	100
1.10	1.07	0.06	1.60	50
1.70	1.68	0.02	2.30	70
2.20	2.23	0.03	3.30	60
2.25	2.27	0.02	4.25	20
4.40	4.45	0.05	5.50	90
3.10	3.04	0.06	5.50	30
6.00	6.05	0.05	7.00	100
4.60	4.54	0.06	7.00	60
4.40	4.41	0.01	9.00	20

Figure 5 - Normal Take-off Distance and Line Speed Check Subchart 2, Prediction of Non-regressed Points

D. OTHER CURVE FITTING METHODS USED

In cases where only two variables were present a simplified method of curve fitting was used. The HP-41C/CV Standard Applications Handbook [Ref. 10] contains a curve fitting program which will fit a linear, logarithmic, exponential or power curve to a two dimensional set of data points. For instance, the power curve fitting routine was used in the top subchart of Figure 3 to obtain lift-off speed (V) as a function of take-off gross weight (W). This resulted in the equation

$$V = 21.41W^{0.4854}$$

which predicts lift-off speed to within one knot.

III. CONCLUSIONS AND RECOMMENDATIONS

The A-6 NATOPS Calculator Aided Performance Planning system applies the concept of NATOPS performance data computerization to a specific aircraft model. This thesis demonstrated the feasability of such an effort by adapting some of the more useful A-6 planning data to a specific computing device and developing the documentation which would be required for use of the programs by the fleet.

The NCAPPS software incorporates only a fraction of the A-6 performance data which is suitable for computerization. This leaves considerable room for expansion, particularly to include the data which describe emergency situations such as the various single engine performance curves. Another useful application would be computerization of the weapons delivery data found in the aircraft Tactical Manual. The charts for sight angles, release sensitivities, dive recovery, fuzing and many others suffer from the same complexities which make the NATOPS material difficult to use. Programs to compute release error sensitivities and wind corrections would be expecially useful for inflight weapon impact analysis.

A shortcoming of the HP-41CV calculator is its limited ability to display program output. A solution is the use of a micro-computer with a video or large liquid crystal display for the NCAPPS system. The recent introduction

of several highly portable, large memory micro-computers makes this an attractive option which should be investigated furthur. An additional benefit would be the ability to use a computer language such as BASIC which would permit greater efficiency and flexibility in programming the performance equations.

The degree of acceptance NCAPPS or similar systems receive at the squadron level is of overriding importance and will ultimately determine whether furthur development is warranted. In their present form the NCAPPS programs are easily understood and simple to operate, minimizing the investment in learning time required by crewmembers. To determine its usefulness, it is recommended that NCAPPS next be evaluated over an extended period by an operational fleet squadron.

A-6E/A-6E TRAM/KA-6D

NATOPS

Calculator Aided

Performance Planning

System

(NCAPPS)

USER'S MANUAL

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INTRODUCTION

The A-6E/A-6E TRAM/KA-6D NATOPS Calculator Aided Performance Planning System (NCAPPS) was designed to increase the speed and accuracy of mission planning. It consists of a series of interactive programs which employ analytic representations of the aircraft performance curves found in the NATOPS Manual [Ref. 1]. These programs enable a user to plan various segments of a mission without the need to refer to complex and often difficult to read graphical charts.

The heart of the NCAPPS system is the Hewlett-Packard HP-41CV hand-held programmable calculator. This device was selected because of its portability, ease of operation, large memory capacity and its ability to provide interactive alphanumeric prompts to the user. In addition, the availability of various mass storage and data retrieval devices for the HP-41CV allows the entire NCAPPS library to be accessed from a single calculator.

The advantages of NCAPPS are speed, accuracy and flexibility. Once familiar with the operation of the calculator and the program library, a user can plan a typical mission almost as fast as the data can be written onto a jet card. Greater accuracy is obtained by eliminating the need to extract and interpolate data from graphical

performance curves, a process extremely susceptable to error. Finally, the ease with which mission parameters can be varied adds to flexibility in mission planning. The ability to experiment with different fuel loads, mission radii, winds aloft, etc. allows the planner to better evaluate the available performance tradeoffs.

Some of the NCAPPS programs are useful during flight operations both by flight crews as well as Tower, PRIFLY, and CATCC personnel. In general, these programs are small enough so that two or three can be loaded into the calculator's program memory simultaneously. As future programs are added to NCAPPS, a full range of programs will be available for inflight and preflight planning use.

The output from NCAPPS is designed to correspond with the information contained in NATOPS. In fact, the programs were developed from data obtained directly from the NATOPS charts. Occasionally roundoff differences or perturbations in the analytic models may cause small discrepancies between the NATOPS results and the program output. Testing of the programs over the range of each variable has shown that these differences are typically insignificant and well within the level of variation due to pilot technique or individual aircraft differences.

THE HP-41CV CALCULATOR

The HP-41CV (Figure 1) is an advanced alphanumeric programmable calculator with sufficient program memory and data storage registers to allow execution of complex general purpose programs which may contain up to several hundred program steps. In addition, programs can be rapidly entered into program memory using a magnetic card reader, a digital cassette drive, memory expansion modules or other available mass storage devices. This capability is necessary since some of the larger NCAPPS programs occupy most of program memory and must be cleared prior to loading another program. The method of program storage will not be discussed furthur here although it is assumed that a viable means of storing the NCAPPS software is available to the user. The appropriate users manuals [Ref. 2] should be consulted for detailed operating instructions.

Once a program is loaded into program memory, execution is quite simple. However, two items must initially be checked. The first is memory register allocation which is simply the number of memory registers set aside either for data storage of for program instructions. By executing "SIZE 027", which allocates 27 data storage registers, all current NCAPPS programs except "DRAG" can be run. (To run "DRAG" execute "SIZE 015".) This is done by depressing

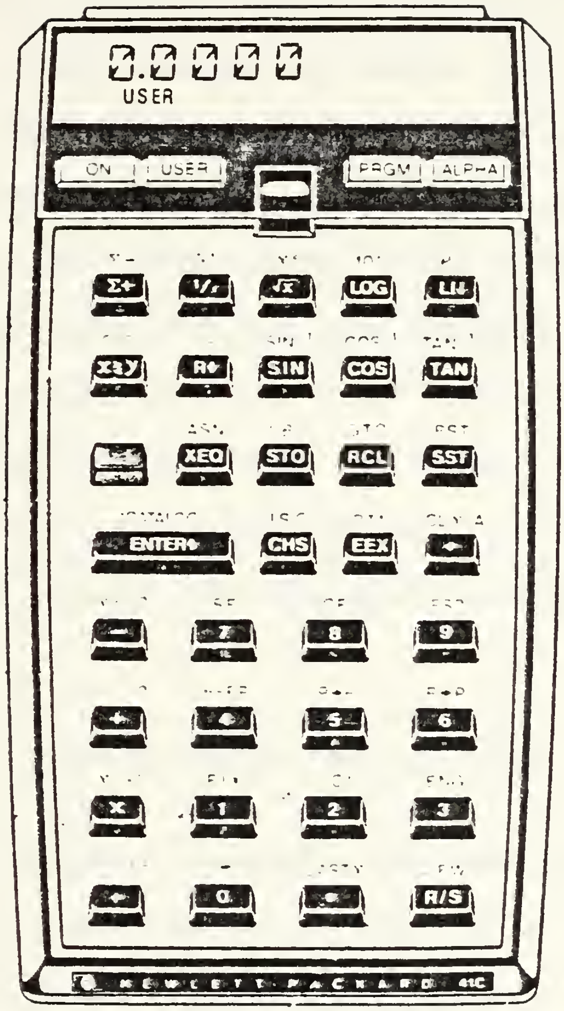


Figure 1 - Hewlett-Packard HP-41CV Calculator

{XEQ} then {ALPHA} which allows alpha characters to be entered, and then spelling S-I-Z-E. Depress {ALPHA} again signifying that the alpha string "SIZE" is complete and note the display "SIZE___". Now enter "027" and observe that the display returns to its original value. You have just executed the function "SIZE" and partitioned 27 data storage registers to be used by NCAPPS. This is essentially the same procedure used to initiate execution of all of the NCAPPS programs. The second item to check is that the calculator is in the "USER" mode. This allows the programs to receive inputs from certain user defined keys and is done by simply depressing the "USER" key on the top panel of the calculator so that "USER" is visable in the display. When the above items are completed and a program has been loaded into main memory, the system is ready to operate.

USER'S MANUAL ORGANIZATION

The NCAPPS program documentation contained in this manual is divided into two sections; a User Procedures section which contains program descriptions, operating instructions and examples, and an Appendix which contains flow charts, program listings, data storage register contents and the equations used to analytically model the NATOPS performance data. By reading the User Procedures section and working through the example problems, a user

with a basic knowledge of the HP-41CV should have no difficulty mastering the system.

USER PROCEDURES

In this section each NCAPPS program is listed as follows:

1. PROGRAM NAME. This is the program name recognized by the calculator for the program in question.
2. PROGRAM DESCRIPTION. This subsection contains a general description of the program including program inputs and outputs and their respective units (knots, feet, pounds, etc.). Special program features and/or limitations are also stated.
3. EXAMPLE PROBLEM AND USER INSTRUCTIONS. An example problem using a typical situation or configuration is presented for each NCAPPS program. Step-by-step instructions showing the exact keystrokes and output displays are provided. Specific key labels are indicated by brackets {}, while numeric or alphanumeric inputs are shown without brackets.
4. REFERENCE. The NATOPS chart used to develop the program is cited. In some of the larger programs such as "CCD" (Climb, Cruise and Descent), many charts are incorporated in the various sub-sections of the program.

GENERAL COMMENTS

1. The user should recognize that a display with a question mark is a prompt requiring an input response. In order to conserve program memory, these prompts have been abbreviated, occasionally requiring some prior familiarity on the part of the user. This is quickly obtained with regular use of the programs.
2. A display with no question mark indicates either an intermediate or final answer or an advisory remark. In most cases the program will halt program execution until the user presses the {R/S} key, allowing time to record the output.
3. At the end of each program, unless stated otherwise, pressing the {R/S} key will return execution back to the beginning of the program allowing repeated runs.
4. If an input is incorrectly entered it may be corrected by pressing the {CLX} key and re-entering it as long as the {R/S} key has not been pressed. If the {R/S} key has been pressed, it is recommended that the program be re-initiated.
5. If the message "NONEXISTENT" is displayed,
   a. Check that the desired program has been loaded.
   b. Ensure that "SIZE 027" (or "SIZE 015" for "DRAG") has been executed.

6. The equations which model the NATOPS data are based on the range of the operating variables found in NATOPS. These ranges are usually sufficient to cover every feasable operating situation. Extrapolation beyond these limits will result in unreliable output and should not be attempted.

ASYMETRIC EXTERNAL STORE LOADING CATAPAULT AND ARREST LIMITATIONS

1. PROGRAM NAME: ASYM

2. DESCRIPTION

This program computes the wing static moment when given the stores load in pounds on stations one, two, four and five. The static moment is displayed (positive for starboard asymmetry and negative for port asymmetry) and the user is advised whether the moment is within limits for catapault or arrested landing. Asymmetry is determined using the relation

(Sta 5 load - Sta 1 load)*11.75 +
(Sta 4 load - Sta 2 load)*7.9 $\leq \pm$21,150.

3. EXAMPLE PROBLEM AND USER INSTRUCTIONS

Two MK 82 Snakeye bombs are hung on each of the station 1 and station 2 MERs. The stations 4 and 5 MERs are empty. Should a shipboard landing be made?

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}ASYM{ALPHA}	STA 2 LOAD?	Enter wing station loads in pounds.
1144 {R/S}	STA 2 LOAD?	
1144 {R/S}	STA 4 LOAD?	

Note: In this example MER weight can be neglected since there are MERs on all four wing stations resulting in symmetry.

0 {R/S}	STA 5 LOAD?	

Keystrokes:	Display:	Instructions:
0 {R/S}	MOMENT= -22,840	
	NO GO	
{R/S}	STA 2 LOAD?	Reinitializes Program

Port static asymmetry is 22,840 ft-lb which exceeds the 21,150 ft-lb allowable. An arrested landing should not be made in this configuration.

4. REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, p. 128, Fig. 1-50, Carrier Limitations.

MAXIMUM RANGE CLIMB, CRUISE AND DESCENT PROFILE

1. PROGRAM NAME: CCD

2. DESCRIPTION

This program calculates all time, distance, fuel and airspeed parameters needed to plan a typical long range mission flown at maximum range airspeeds and optimum cruise altitude. The program will permit sufficient deviation from optimum cruise altitude to allow compliance with ATC altitude restrictions. Launch and recovery at sea level are assumed.

Analytical representations of performance data obtained from various NATOPS climb, cruise and descent graphs are used to generate program output which is valid for any allowable gross weight, fuel load or external load. During each phase of the mission profile the aircraft gross weight is updated to provide accurate calculations. Forecast climb, cruise and descent winds as well as outside air temperature deviations of up to 20 degrees Celsius (from ICAO Standard) can be incorporated.

The program contains several distinct subsections which are summarized as follows:

a. Data Input. The following information is input using interactive prompts from the calculator:

(1) Aircraft empty weight in pounds.

(2) Initial fuel weight in pounds (including external fuel).

(3) External stores weight in pounds (excluding drop tank fuel).

(4) Drag count.

(5) Total mission distance in nautical miles.

(6) Average climb headwind or tailwind component in knots (all wind entries will assume a positive headwind or a negative tailwind. Depress {CHS} to indicate a negative value).

(7) Average descent headwind or tailwind component in knots.

(8) Expected deviation from ICAO Standard Day temperatures in plus or minus degrees Celsius during the climb and/or cruise phases of the mission.

(9) Estimated fuel consumed during start, taxi and takeoff (STTO) in pounds.

b. Optimum Altitude. The program will display the optimum cruise altitude as a flight level (i.e. FL335 indicates a pressure altitude of 33,500 ft). The user responds by entering the desired 3-digit flight level. To ensure programm accuracy, this should be within 2000 feet of the optimum altitude displayed previously.

c. Climb and Descent. The program now calculates climb

and descent times and distances. If the sum of the climb and descent distances are greater than the total mission distance, no cruise legs are calculated and a peak altitude where the pilot should transition from a climb to a descent is computed. The routine for calculating this altitude and distance is described in the appendix.

d. Climb. Climb distance in nautical miles, climb time in minutes and climb fuel in thousands of pounds are displayed. Also, climb calibrated airspeed and the passing flight level at which 0.7 mach should be intercepted are shown. This climb profile ensures that optimum climb distance, time and fuel consumed are obtained.

e. Cruise. Once the user has obtained the climb distance above, the number of cruise legs can be determined. This is normally based on distances between airway or mission checkpoints, but can also be based on the expected winds along the route of flight. It may be advantageous to split a single long leg into more than one segment if the winds vary significantly along that leg. For quick estimating, the user may also decide to represent the cruise portion as just a single leg to simplify the calculations.

The program prompts for the number of cruise legs and then displays the distance remaining to the descent point. If the user enters a distance greater than the distance remaining, the program repeats the prompt until a

satisfactory response is obtained. The user should ensure that the distance entered for the last cruise leg is the same as the distance remaining to the descent point.

Next the program prompts for the leg wind. This is the average headwind or tailwind component for the leg and is entered using the convention given above.

The program will display, for each leg, the best range mach number, true airspeed, ground speed, elapsed time in minutes, fuel flow in pounds per hour, leg fuel consumed in thousands of pounds, and fuel remaining at the completion of the leg in thousands of pounds.

f. Descent. After completing the cruise calculations (or climb calculations if no cruise legs are required) the program will calculate and display the descent point in nautical miles from the destination, descent time in minutes and descent fuel in thousands of pounds.

g. Mission Summary. The final portion of the program displays total time enroute in minutes, fuel remaining at the destination in thousands of pounds and total fuel required in thousands of pounds.

3. EXAMPLE PROBLEM AND USER INSTRUCTIONS

Aircraft: A-6E TRAM with turret, full internal fuel with a full AERO-1D drop-tank mounted on station 3, 4 empty MERs loaded on stations 1,2,4 and 5.

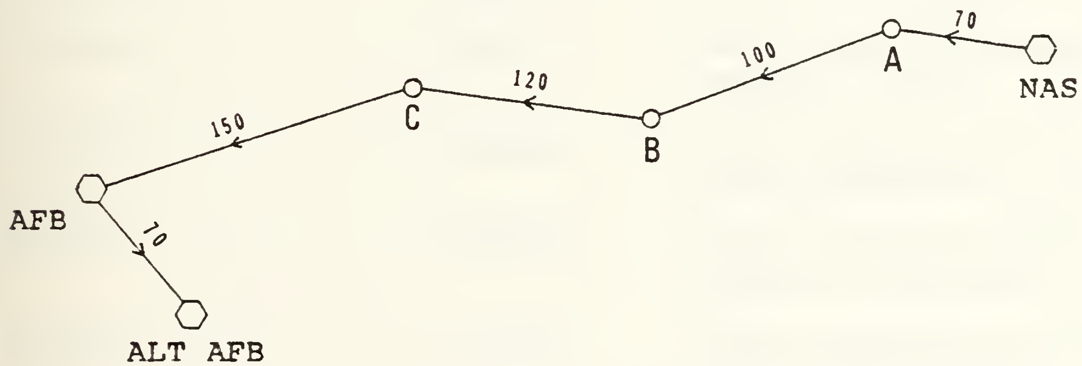
Weight:	Empty aircraft			28,300
	Fuel	Internal	15,939	
		External	2,040	17,979
	Stores	AERO-1D	198	
		4 MERS	856	1,054
Total weight				47,333 lbs

Drag count: (use DRAG program) 42

Mission: Field launch, high altitude airways, field recovery.

Route of flight: Distance to destination 440 nm

Destination to alternate 70 nm



Start, Taxi and Takeoff fuel: 700 pounds

Forecast winds:

Segment	Headwind Component[kts]
NAS to A (climb)	10
A to B (FL350)	40
B to C	80
C to descent pt.	20

Segment	Headwind Component
Descent	10
AFB to ALT AFB	-10

Temperature deviation from ICAO Standard Day: 0

Plan the above mission.

IMPORTANT: Before running this program the calculator must be properly partitioned. Set SIZE 027 (see following page).

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}SIZE{ALPHA}	SIZE---	Memory size is 027.
027	SIZE 027	
{XEQ}{ALPHA}CCD{ALPHA}	EMPTYWT?	Enter A/C empty weight in pounds.
28300{R/S}	FUELWT?	Enter total fuel weight in pounds.
17979{R/S}	STOREWT?	Enter external store weight in pounds.
1054{R/S}	DRAG?	Enter drag count.
42{R/S}	DIST?	Enter total distance in nautical miles.
440{R/S}	CLWIND?	Enter average climb headwind component in kts.
10{R/S}	DSWIND?	Enter average descent headwind component.
10{R/S}	T DEV?	Enter temperature deviation from standard in degrees Celsius.
0{R/S}	STTO?	Enter start, taxi and takeoff fuel in pounds.
700{R/S}	OPT FL349	Optimum FL - continue.
{R/S}	CRSE FL?	Enter desired cruise FL.

Keystrokes:	Display:	Instructions:
350{R/S}	CLDIST 69NM	Climb distance to FL350.
{R/S}	CLTIME 10MIN	Climb time.
{R/S}	CLFUEL=1.8	Climb fuel is 1800 lb.
{R/S}	CL AT 303KCAS	Best climb indicated A/S.
{R/S}	.7M AT FL218	Fly 0.7 mach from FL218 to FL350.
{R/S}	N CRSE LEGS?	Enter number of cruise legs.

Since the climb distance of 69 nm nearly coincides with the first check point, and the descent distance will be less than the last leg distance of 150 nm, 3 cruise legs are assumed.

3{R/S}	CRDIST 293NM	Remaining cruise distance is 293 nm - continue.
{R/S}	LEG 1 NM?	Enter the distance of the first cruise leg.
101{R/S}	LEGWIND?	Enter the forecast average headwind for leg 1.
40{R/S}	LEG M=0.73	Best range mach, leg 1.
{R/S}	TAS=421	Leg 1 TAS in knots.
{R/S}	GS=481	Leg 1 ground speed in knots.
{R/S}	TIME 16 MIN	Leg 1 elapsed time.
{R/S}	FF=3900PPH	Leg 1 fuel flow.
{R/S}	LEGFUEL=0.9	Leg 1 fuel is 900 pounds
{R/S}	FUELQTY=14.6	Fuel remaining at point B is 14,600 pounds.
{R/S}	CRDST 192NM	Remaining cruise distance.

Keystrokes:	Display:	Instructions:
{R/S}	LEG 2 NM?	Enter crusie leg 2 dist.
120{R/S}	LEGWIND?	
80{R/S}	LEG M=0.72	
{R/S}	TAS=418	
{R/S}	GS=338	
{R/S}	TIME 21MIN	
{R/S}	FF=3750PPH	
{R/S}	LEGFUEL=1.1	
{R/S}	FUELQTY=13.5	
{R/S}	CRDIST 72NM	72 nm remain to the descent point.
{R/S}	LEG 3 NM?	Final cruise leg. Same as above distance.
72{R/S}	LEGWIND?	
20{R/S}	LEG M=0.72	
{R/S}	TAS=415	
{R/S}	GS=395	
{R/S	TIME 11MIN	
{R/S}	FF=3630PPH	
{R/S}	LEGFUEL=0.6	
{R/S}	FUELQTY=12.9	
{R/S}	DS AT 78NM	Begin descent 78 nm from destination.
{R/S}	DSTIME 16MIN	Descent time.
{R/S}	DSFUEL=0.4	Descent fuel.
{R/S}	ΣTIME 74MIN	Total mission time.

Keystrokes:	Display:	Instructions:
{R/S}	DESTFUEL=12.5	Fuel remaining at destination.
{R/S}	ΣFUEL=5.5	Total fuel required to reach destination.

To continue to the alternate:

{R/S}	EMPTYWT?	
28300{R/S}	FUELWT?	
12500{R/S}	STOREWT?	
1054{R/S}	DRAG?	
42{R/S}	CLWIND?	Tail wind is entered as a negative value.
10{CHS}{R/S}	DSWIND?	
10{CHS}{R/S}	T DEV?	
0{R/S}	STTO?	
0{R/S}	OPT FL370	
{R/S}	CRSE FL?	
370{R/S}	NO CRSE LEG CL TO FL159	

Due to the short distance no cruise leg is necessary. Climb to FL159 then immediately begin the descent leg.

{R/S}	CL AT 303KCAS	
{R/S}	CLTIME 4MIN	
{R/S}	CLDIST 28NM	
{R/S}	CLFUEL=1.0	
{R/S}	DSTIME 8MIN	
{R/S}	DSDIST 32NM	
{R/S}	ΣTIME 11MIN	Time to fly from destination to alternate.

Keystrokes:	Display:	Instructions:
{R/S}	DESTFUEL=11.3	Fuel at alternate.
{R/S}	ΣFUEL=1.2	Fuel to fly from destination to alternate.

4. REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, Chapter 11:

Figure 11-93, Military Power Climb, Climb Speed Schedule

Figure 11-94, Military Power Climb, Time Required to Climb From Sea Level to Selected Altitude

Figure 11-95, Military Power Climb, Fuel Required to Climb From Sea Level to Selected Altitude

Figure 11-96, Military Power Climb, Distance Required to Climb From Sea Level to Selected Altitude

Figure 11-103, Maximum Range Cruise at a Constant Altitude, Time and Speed

Figure 11-107, Maximum Range Descent, Time Required to Descend From Selected Altitude to Sea Level at Idle Power

Figure 11-110, Maximum Range Descent, Fuel Required to Descend From Selected Altitude to Sea Level at Idle Power

Figure 11-111, Maximum Range Descent, Distance required to Descent From Selected Altitude to Sea Level at Idle Power.

DRAG COUNT AND EXTERNAL STORES WEIGHT

1. PROGRAM NAME: DRAG

2. DESCRIPTION

This program computes drag counts and external stores weight for many commonly carried A-6 weapon/stores loads (listed below). Calculations may be made for mixed load and various rack configurations. The A-6 Tactical Manual and NATOPS Manual should be consulted for load and weight restrictions.

AVAILABLE STORES LOADS

AERO-1D DROP TANK* (-2040/empty tank weight correction)
MK 25 Mine* (-117lb/mine weight correction)
MK 25 Drill Mine
MK 52 Mine
MK 52 Drill Mine* (-41lb/mine weight correction)
MK 55 Mine
MK 55 Drill Mine* (-65 lb/mine weight correction)
MK 56 Mine
MK 56 Drill Mine* (-66lb/mine weight correction)
MK 45 Parachute Flare (use for MK 24 or LUU-2B/B flare)
MK 58 Marine Location Marker
MK 76 Practice Bomb
MK 81 Conical Tail
MK 81 Snakeye
MK 86 Practice Bomb

MK 82 Conical Tail

MK 82 Snakeye (Use for MK 36 DST and MK 124 Practice Bomb)

MK 82 Laser Guided Bomb

MK 87 Practice Bomb

MK 83 Conical Tail

MK 83 Laser Guided Bomb

MK 88 Practice Bomb

MK 84 LDGP

MK 84 Laser Guided Bomb

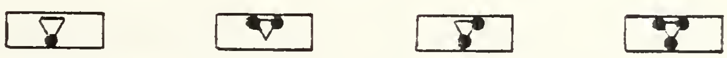
MK 41 DST

*The store weight calculated by the program must be adjusted by the factor given.

3. PROGRAM OPERATION

a. The program operates interactively, receiving responses from the top two rows of keys.

ROW 1: | YES | | NO | | MER | | TER | | AERO |

ROW 2: | EMPTY | 

The meanings of these keys are as follows. IMPORTANT: The calculator must be in the "USER" mode for the above keys to operate as defined.

| YES | Yes response

| NO | No response

| MER | A Multiple Ejector Rack (MER) is loaded on the station(s) in question.

[TER] A Triple Ejector Rack (TER) is loaded on the station(s) in question.

[AERO] Weapon/store will be loaded directly on the AERO-7A or AERO-7B rack.

[EMPTY] No stores including ejector racks are to be loaded on the station(s) in question,

OR

No stores are to be loaded on the MER or TER which is loaded on the station(s) in question.

[▽], [▽], [▽], [▽] Indicates to the program the TER load configuration or (as prompted by the program) the forward or aft MER load configuration for the station(s) in question.

b. Symmetrical loads are assumed. That is, whatever load is on station 1 is also on station 5; and similarly with stations 2 and 4. Centerline (station 3) loads are symmetric about the station axis. Mixed loads between inboard, outboard and centerline stations are permitted.

c. For each station pair the program will inquire which store is to be loaded (i.e. "STA 1/5 STORE?"). At this time the NUMERIC part of the store name should be entered. For example, if MK 82 Snakeye bombs are to be loaded on stations 1 and 5, the user should enter "82" and depress the {R/S} button. The user will then use the top two rows of user defined keys to respond to subsequent program prompts.

d. If an unauthorized store configuration is entered a tone will sound and the message "NON-STD LOAD" will be displayed. Depress {R/S} to reinitiate the program. Be sure to check NATOPS and the Tactical Manual for furthur restrictions.

e. The program includes the weights of ejector racks in its weight calculations. It also makes the necessary adjustments to drag count to allow for unloaded inboard or outboard wing stations.

f. The user is asked to specify whether or not a TRAM turret is installed. If the response is "NO", 18 will be subtracted from the total drag count. This permits the possibility of a "negative" drag count for some configurations which should be taken as zero for planning purposes.

4. EXAMPLE PROBLEM AND USER INSTRUCTIONS

You are to carry 12 MK 82 Snakeye loaded on MERs on stations 1 and 5. A single AERO-1D drop tank is loaded on station 3 and stations 2 and 4 are empty. Your aircraft is TRAM configured. What is your drag count and stores weight?

If using a card reader for program storage, insert the first card into the clip above the display window. It should be annotated as follows corresponding to the top two rows of keys.

YES	NO	MER	TER	AERO	(Row 1)
EMPTY					(Row 2)

It will assist you in responding to program prompts.

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}DRAG{ALPHA}	SELECT USER	Select "user" mode if you have not already done so.
(none)	TURRET?	Enter "Yes" if TRAM.
{YES}	1/5 STORE?	Enter the numeric code of the store to be loaded on stations 1/5.
82{R/S}	MER/TER/AERO?	Enter rack type.
{MER}	(FWD)CONFIG?	For a TER (FWD) would be ignored.
{ }	AFT CONFIG?	
{ }	LGB?	Laser Guided Bomb?
{NO}	SNAKEYE?	
{YES}	2/4 STORE?	
{EMPTY}	3 STORE?	Enter the code for an AERO-1D drop tank.
1{R/S}	MER/TER/AERO	
{AERO}	1/5 DRAG=56	0.7 X 80 = 56 (stations 2 and 4 are empty).
{R/S}	2/4 DRAG=0	
{R/S}	3 DRAG=10	
{R/S}	TOT DRAG=66	
{R/S}	STORES WT=9530	
{R/S}	SELECT USER	Reinitializes program.

5. REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, pp. 11-114-5, FO-17.

LANDING AND APPROACH SPEEDS

1. PROGRAM NAME: LAA

2. PROGRAM DESCRIPTION

This program computes the power approach stall speed (V), stall warning speed, minimum landing distance approach speed and optimum approach speed for the A-6E, A-6E TRAM and KA-6D aircraft. The user inputs aircraft gross weight in thousands of pounds and also indicates to the program whether or not external stores are carried. The program assumes takeoff flaps (30°), gear down and wing tip speed brakes extended.

3. EQUATIONS

$$V_s = 48.25 + 1.375W$$

$$V_{sw} = 1.09V$$

$$V_{mld} = 1.18V$$

$$V_{app} = 1.28V$$

Where V_s = power approach stall speed

W = gross weight [lbs/1000]

V_{sw} = stall warning speed

V_{mld} = minimum landing distance approach speed

V_{app} = optimum approach speed.

4. EXAMPLE PROBLEM AND USER INSTRUCTIONS

Compute power approach stall speed, stall warning speed, minimum landing distance approach speed and optimum

approach speed for a 36,000 pound aircraft with drop tanks and MERs.

{XEQ}{ALPHA}LAA{ALPHA}	GW/1000?	Enter gross weight in thousands of pounds.
36{R/S}	STORES? A=NO	If no external stores are loaded press {A}. If stores are loaded press {R/S}.
{R/S}	VSTALL=98	Power approach stall speed [KIAS].
{R/S}	VWRNG=107	Stall warning speed.
{R/S}	VMINAPP=115	Minimum landing distance approach speed.
{R/S}	VOPTAPP=125	Optimum approach speed.
{R/S}	GW/1000?	Reinitializes program.

REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, p. 11-62, Fig. 11-51, Landing and Approach Speeds.

MAXIMUM REFUSAL SPEED (SINGLE ENGINE)

1. PROGRAM NAME: RS

2. PROGRAM DESCRIPTION

This program computes maximum refusal speed which is the maximum takeoff engine failure speed at which the aircraft can be brought to a stop at the end of the runway. Use of antiskid braking and flaperon pop-up are assumed. Input are aircraft gross weight in thousands of pounds, local pressure altitude in feet, temperature in degrees Fahrenheit, actual runway length in feet, headwind or tailwind component in knots and runway slope gradient in degrees.

3. EXAMPLE PROBLEM AND USER INSTRUCTIONS

Compute refusal speed for a 46,000 pound aircraft on a 4400 foot runway with a pressure altitude of 2600 feet, a surface temperature of 77 degrees Fahrenheit, a 10 knot headwind and a positive runway slope gradient of 1 percent.

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}RS{ALPHA}	GW/1000?	Enter gross weight in thousands of pounds.
46{R/S}	P.ALT: FT?	Enter pressure altitude in feet.
2600{R/S}	TEMP: F?	Enter temperature in degrees Fahrenheit.
77{R/S}	RWY LT: FT?	Enter runway length.

Keystrokes:	Display:	Instructions:
4400{R/S}	+HW/-TW: KTS?	Enter Headwind or tailwind in knots, headwind positive/ tailwind negative.
10{R/S}	RWY GRAD?	Enter runway slope gradient in percent.
1{R/S}	REFSPD: 110	Refusal speed in knots.
{R/S}	GW/1000?	Reinitializes program.

REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, p. 11-18, Fig 11-11, Maximum Refusal Speeds.

TANKER MISSION PROFILE - KA-6D

1. PROGRAM NAME: TANK

2. PROGRAM DESCRIPTION

This program computes, for the KA-6D Tanker, the amount of give away fuel available based on current fuel onboard, time until recovery and holding profile. The computed value allows the aircraft to leave holding at recovery time with approximately 5000 pounds of fuel remaining. Two holding profiles may be selected: a) low holding at 2000 feet, 210 KCAS or b) high holding at 15,000 feet, 210 KCAS.

3. EXAMPLE PROBLEM AND USER INSTRUCTIONS

You have 20,000 pounds of fuel onboard and one hour until recovery. For a 15,000 foot holding pattern, what is your give away fuel.

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}TANK{ALPHA}	FUEL ONBD/1000?	Enter fuel onboard.
20{R/S}	HRS TO REC?	Enter hours until recovery.
1{R/S}	A=LOW,B=HIGH	Press {A} for low holding, {B} for high holding.
{B}	GIVEAWAY:10.9	
{R/S}	FUEL ONBD/1000?	Reinitializes program.

4. REFERENCE

NAVAIR 01-85ADF-1B, NATOPS Pocket Checklist A-6E/A-6E TRAM/ KA-6D [Ref. 3], p. 82, Tanker Mission Profile - KA-6D.

NORMAL TAKEOFF DISTANCE AND LINE SPEED CHECK

1. PROGRAM NAME: TO

2. PROGRAM DESCRIPTION

This program calculates takeoff ground roll distance in feetand lift-off equivalent airspeed (EAS) in knots. Inputs are takeoff gross wieght in thousands of pounds, runway temperature in degrees Fahrenheit, runway pressure altitude in feet, headwind component in knots and runway slope gradient in percent. All external store configurations are valid. The program also computes line speed at any point along the takeoff ground roll up to 5000 feet when given this distance in feet. Warnings are provided for situations where excessive ground roll would result in marginal or unsafe conditions.

3. EXAMPLE PROBLEM AND USER INSTRUCTIONS

Takeoff gross weight: 45,000 pounds

Runway Temperature: 80 Degrees Fahrenheit

Runway pressure altitude: 3000 feet

Headwind component: 20 knots

Runway slope gradient: 2 percent

Find takeoff distance, liftoff speed, speed at 2000 feet and speed at 3000 feet.

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}TO{ALPHA}	GW/1000?	Enter gross weight in thousands of pounds.

Keystrokes:	Display:	Instructions:
45{R/S}	TEMP?: DEG F	Enter runway temperature.
80{R/S}	PRES ALT?: FT	Enter runway pressure altitude.
3000{R/S}	WIND?: KTS	Enter positive headwind or negative tailwind.
20{R/S}	GRADIENT?: %	Enter runway slope gradient.
2{R/S}	T/O DIST=3380	Take-off distance in feet.
{R/S}	CK DIST?: FT	Enter linespeed distance in feet.
2000{R/S}	L/S=108 KIAS	Line speed at 2000 ft.
{R/S}	CK DIST?: FT	
3000{R/S}	L/S=131 KIAS	Line speed at 3000 ft.

4. REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, p. 11-19, Fig. 11-12, Normal Take-off Distance and Line Speed Check.

CROSSWIND TAKEOFF/LANDING

1. PROGRAM NAME: XWL

2. PROGRAM DESCRIPTION

This program computes cross-wind and headwind components as well as nose-wheel touchdown/liftoff true airspeeds when given runway heading in degrees, wind velocity in knots and wind direction in degrees. Landing is recommended or not recommended based on the maximum sideslip angle of the aircraft using maximum rudder deflection.

3. EXAMPLE PROBLEM AND USER INSTRUCTIONS

You are on an approach to runway 23. Tower advises surface winds are 280/30. Should an arrested landing be made?

Keystrokes:	Display:	Instructions:
{XEQ}{ALPHA}XWL{ALPHA}	RWY HDG?	Enter runway heading in degrees.
230{R/S}	WIND DIR?	Enter wind direction in degrees.
280{R/S}	WIND VEL?	Enter wind velocity in knots.
30{R/S}	RECOMMENDED	A field landing can be made.
{R/S}	MIN TAS=90	Minimum nose-wheel touchdown speed.

Note: For takeoff this minimum overrides computed takeoff speed.

{R/S}	HW=19	Headwind component.

Keystrokes:	Display:	Instructions:
{R/S}	XW=23	Crosswind component.
{R/S}	RWY HDG?	Reinitializes program.

REFERENCE

A-6E/A-6E TRAM/KA-6D NATOPS Manual, p. 11-12, Fig. 11-9, Take-off/Landing Crosswind Chart.

APPENDIX

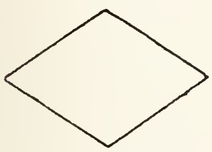
This Appendix contains detailed documentation of each NCAPPS program. This includes the following:

1. EQUATIONS. This section lists the equations used to model the NATOPS performance data. In most cases these are the result of computer generated multiple linear regressions of transformed powers and cross products of the independent variables. In some cases more simple power curves or even linear fits were obtained. Each dependent and independent variable is defined in terms of the units used by the program.

2. FLOWCHARTS. This section contains flowcharts which depict the logic sequence and computational steps used by the programs. The following symbols are used:

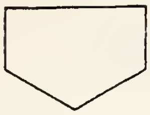
Entry/exit block. Indicates the start or end of the program or a return to the main program from a subroutine.

Process block. Indicates a calculation, data storage or retrieval, input, output or prompt. These operations may be combined in a single block for brevity.



Decision block. Indicates a decision between one of two options.

Branch input. Control is transferred from another part of the program to this point.



Offpage connector. Continuation of a branch from the previous page.

Subroutine execution.

3. PROGRAMS AND SUBROUTINES USED. This section lists the names and a brief description of any subroutines used by the main program.

4. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS. This section lists any flags used by the program and indicates their purpose. It also lists data storage size and the variables or constants assigned to each data storage register. Lastly, the number of registers and bytes required to store the program are given.

5. PROGRAM LISTINGS. This section contains a listing of each line of the program and its appended subroutines.

ASYM - ASYMETRIC EXTERNAL STORE LOADING CATAPAULT AND ARREST LIMITATIONS

1. EQUATIONS

Wing moment:

$$(\text{STA 5 load} - \text{STA 1 load})11.75 + (\text{STA 4 load} - \text{STA 2 load})7.9 \le \pm 21{,}150 \text{ ft-lb}$$

2. FLOWCHART

See following page.

3. PROGRAMS AND SUBROUTINES USED

None.

4. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS.

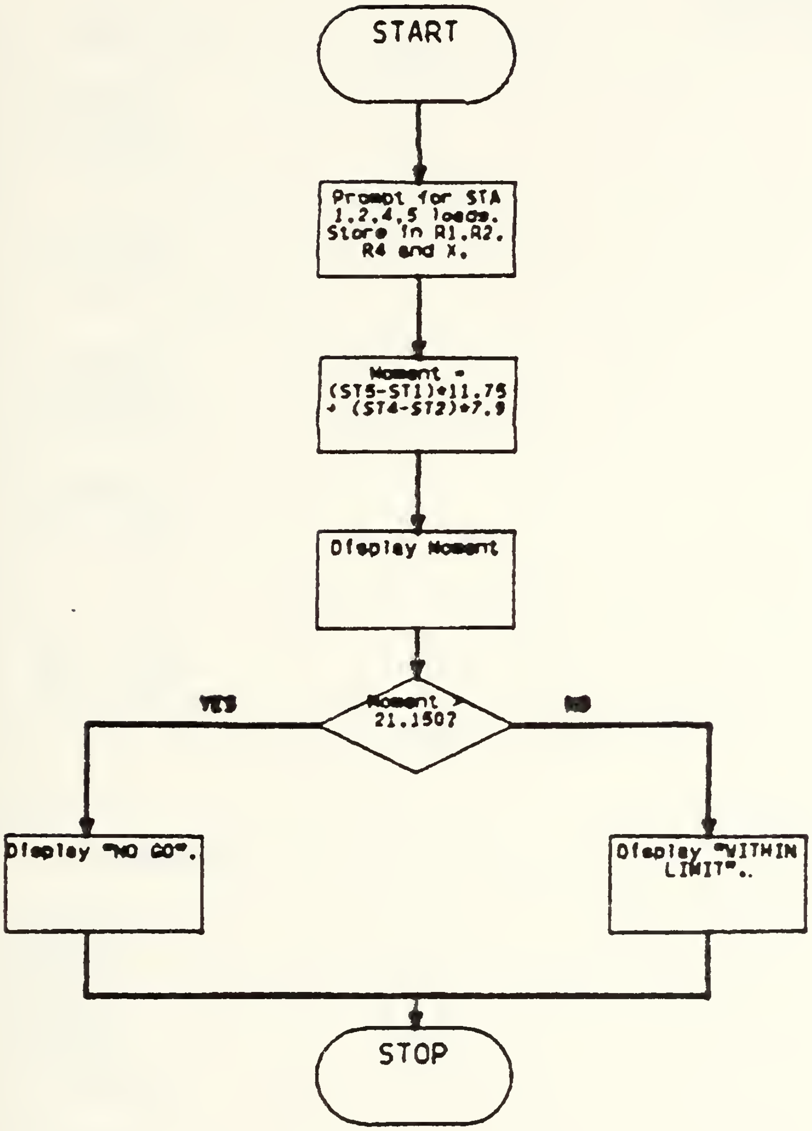
a. Flags used: none.

b. Data storage registers.

Register:	Contents:
R01	Station 1 load in pounds
R02	Station 2 load in pounds
R04	Station 4 load in pounds
R05	Station 5 load in pounds

c. Program storage requirement is 20 registers, 139 bytes.

ASYM


START
Prompt for STA 1,2,4,5 loads. Store in R1,R2, R4 and X.
Moment = (ST5-ST1)*11.75 + (ST4-ST2)*7.9
Display Moment
Moment > 21.150?
YES
Display "NO GO".
Display "WITHIN LIMIT".
STOP

5. PROGRAM LISTING

```
 01♦LBL "ASY
M"
 02 FIX 0
 03 "STA 1 L
OAD?"
 04 PROMPT
 05 STO 01
 06 "STA 2 L
OAD?"
 07 PROMPT
 08 STO 02
 09 "STA 4 L
OAD?"
 10 PROMPT
 11 STO 04
 12 "STA 5 L
OAD?"
 13 PROMPT
 14 RCL 01
 15 -
 16 11.75
 17 *
 18 RCL 04
 19 RCL 02
 20 -
 21 7.9
 22 *
 23 +
 24 "MOMENT=
"
 25 ARCL X
 26 AON
 27 PSE
 28 AOFF
 29 ABS
 30 21150
 31 -
 32 X<0?
 33 GTO 01
 34 "NO GO"
 35 AVIEW
 36 STOP
 37 GTO "ASY
M"
 38♦LBL 01
 39 "WITHIN
LIMIT"
 40 AVIEW
 41 END
```

CCD - MAXIMUM RANGE CLIMB, CRUISE AND DESCENT PROFILE

1. EQUATIONS

a. Optimum cruise altitude [feet/1000].

$$A = 55.27 - 0.4310W - 2.772\times10^{-6}D^2W$$

b. Time required to climb to optimum altitude from sea level [minutes].

$$t_C = \exp(-0.0569 + 3.76\times10^{-3}D - 0.0385W + 6.27\times10^{-3}WA - 1.59\times10^{-5}W^2A - 9.87\times10^{-5}A^2W - 1.86\times10^{-8}D^3 + 1.56\times10^{-5}A^3)$$

c. Time required to climb to optimum altitude from sea level corrected for deviation of temperature from standard in degrees Celsius [minutes].

$$t_C' = 1.41 + 0.500t_C - 4.42\times10^{-3}E^2 + 3.30\times10^{-2}t_C^2 + 1.45\times10^{-3}E^2t_C + 2.68\times10^{-3}Et_C^2 + 1.23\times10^{-4}E^3$$

d. Distance required to climb to optimum altitude from sea level [nautical miles].

$$L_C = \exp(7.65 + 6.63\times10^{-3}D - 0.111W - 0.0483A + 4.32\times10^{-5}W^2A - 1.81\times10^{-6}A^2D - 4.69\times10^{-8}D^3)$$

e. Distance required to climb to optimum altitude from sea level corrected for deviation of temperature from standard in degrees Celsius [nautical miles].

$$L_C' = -1.88 - 0.956E + 1.03L_C + 0.0441EL_C + 9.82\times10^{-4}E^2L_C + 8.65\times10^{-4}E^3$$

f. Fuel required to climb to optimum altitude from sea level [pounds/100].

$$F_C = 7.94 - 0.07D + 8.73\times10^{-5}AW^2 + 8.69\times10^{-5}ADW$$

g. Fuel required to climb to optimum altitude from sea level corrected for deviation of temperature from standard in degrees Celsius [pounds].

$$F_C' = -2.99 - 4.76E + 96.7F_C + 0.954EF_C + 0.0295E^2F_C$$
$$+ 0.0392EF_C^2 + 0.0129E^3 + 0.0143F_C^3$$

h. Best range mach number at optimum altitude.

$$M = 0.345 + 3.00\times10^{-3}W - 2.48\times10^{-5}AD + 3.67\times10^{-7}A^2D$$
$$+ 8.48\times10^{-6}A^2W - 2.28\times10^{-9}A^3W^2 + 2.27\times10^{-10}AD^2W$$

i. Pounds of fuel per nautical mile at optimum altitude [pounds/nm].

$$F = 25.7 - 0.509A + 6.13\times10^{-4}DW - 2.42\times10^{-2}WA$$
$$+ 1.69\times10^{-4}W^2A + 4.81\times10^{-4}A^2W$$

j. True airspeed corrected for temperature deviation in degrees Celsius from standard [knots].

$$TAS = 29.06\ MT^{0.5}$$

$$T = \begin{cases} 518.7 - 3.566A + 1.8E, & (0 \leq A \leq 36) \\ 390 + 1.8E, & (A > 36) \end{cases}$$

k. Best climb speed to optimum altitude [KCAS].

$$V_C = 320 - 0.4D$$

l. Climb flight level at which to intercept 0.7 mach.

$$A_X = 19.7\exp(0.00239D)$$

m. Time required to descend (best range) from optimum altitude to sea level [minutes].

$$t_d = 7.13 + A^3(2.35\times10^{-4} + 4.05\times10^{-12}D^3 - 1.68\times10^{-8}DW)$$

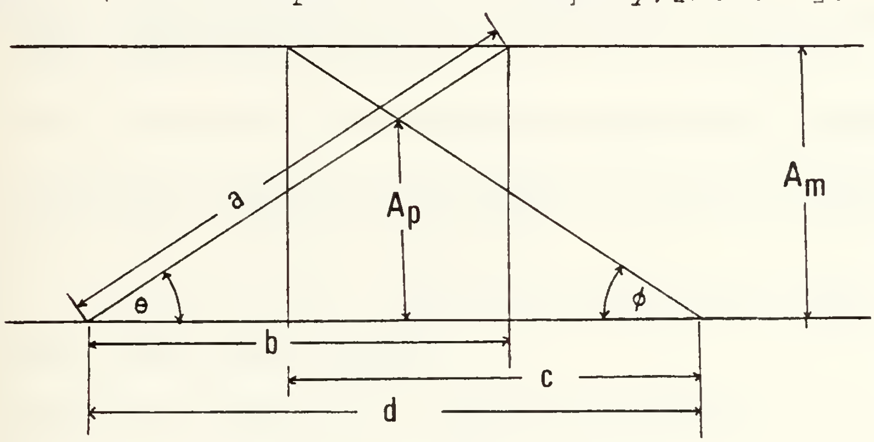
n. Distance required to descend from optimum altitude to sea level [nautical miles].

$$L_d = -31.0 + 3.59A - 8.94x10\ \ AD\ W - 1.67x10\ A\ DW$$
$$+ 1.51x10\ A\ D\ W - t_d V_W$$

o. Fuel required to descend from any altitude to sea level. [pounds/1000].

$$F_d = 0.049\exp(-1.63x10^{3}D)[0.723A^{0.715} - (0.03 + 0.002A)(W - 30)]$$

p. Peak altitude for profiles too short to contain cruise segments (after Campbell and Champney)[Ref. 4].



b = climb distance [NM]

c = descent distance [NM]

d = total mission distance [NM]

A_p = peak altitude [ft/1000]

A_m = optimum altitide = A/6076 [ft/1000/6076]

$\theta = \arctan(A_m/b)$

$\phi = \arctan(A_m/c)$

$a = (d\sin\phi)/\sin(180 - \theta - \phi)$

$A_p = (6076 d\sin\phi\sin\theta)/\sin(180 - \theta - \phi)$

VARIABLES:

A = optimum cruise altitude [ft/1000]

A_m = optimum altitude [ft/1000]

A_p = peak altitude [ft/1000]

A_x = flight level at which mach = 0.7 is intercepted during climb.

D = drag count

E = deviation of temperature from ICAO standard [degrees Celsius]

F = pounds of fuel per nautical mile at cruise altitude [pounds/NM]

F_c = fuel required to climb to optimum altitude from sea level [pounds/100]

F_d = Fuel required to descend to sea level [pounds]

L_c = Distance required to climb to optimum altitude from sea level [nautical miles]

L_c' = L_c corrected for temperature deviation [nm]

M = best range mach number

T = absolute temperature [degrees Rankine]

TAS = true airspeed [knots]

t_c = time to climb to optimum altitude from sea level [min]

t_c' = t_c corrected for temperature deviation [min]

t_d = time to descend from optimum altitude to sea level [min]

V_w = headwind component [KCAS]

V_c = climb airspeed [KCAS]

W = aircraft gross weight [pounds/1000]

3. PROGRAMS AND SUBROUTINES USED

"CL" - Computes climb time, fuel and distance.

"CS" - Computes climb speed and altitude to intercept mach 0.7.

"DF" - Computes fuel used during descent.

"DS" - Computes descent time and distance.

4. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS.

a. Flags used: none.

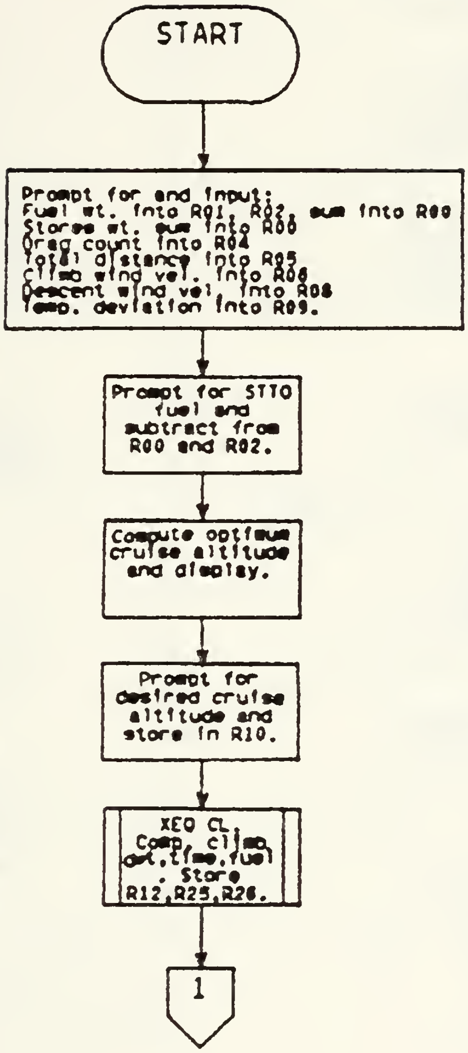
b. Data Storage Registers.

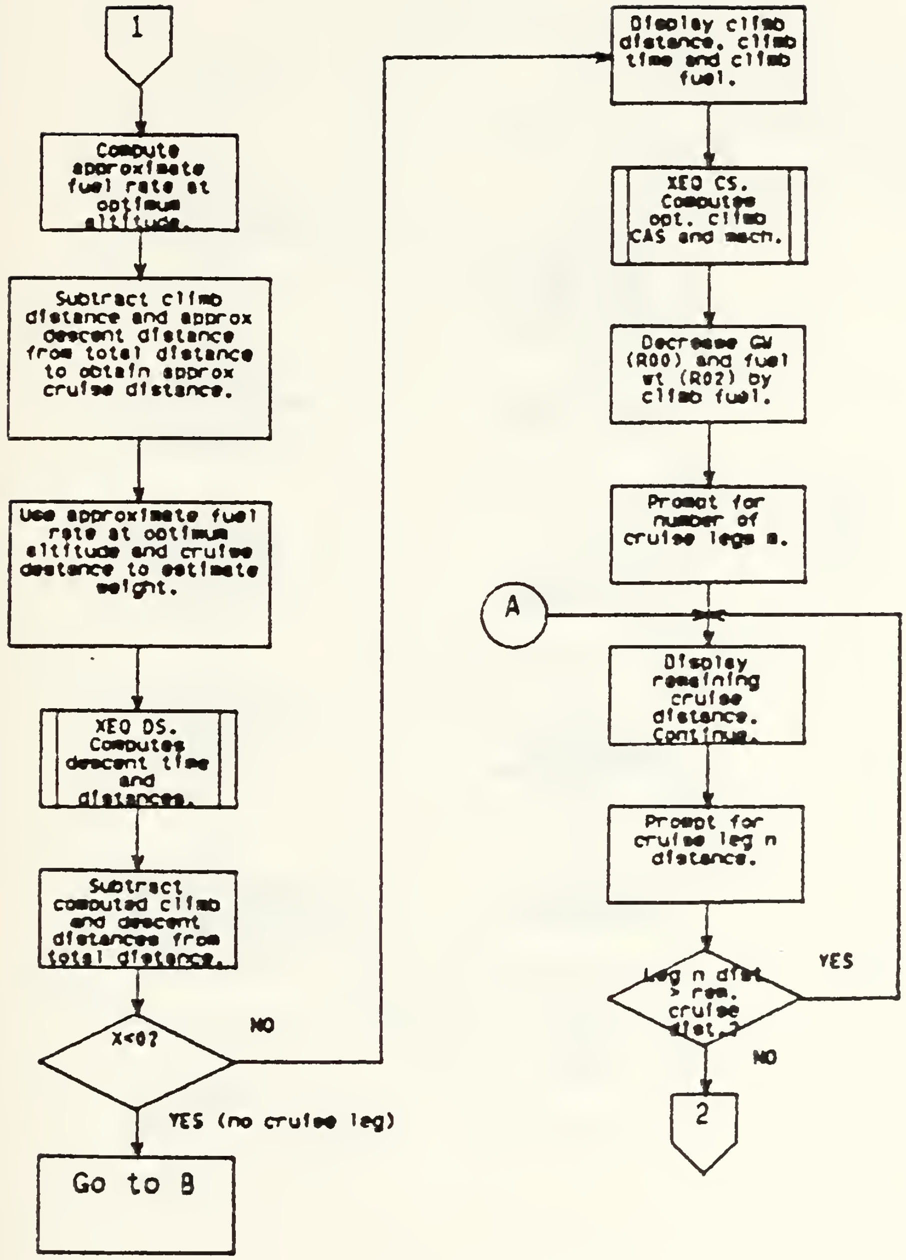
Register:	Contents:
R00	Aircraft gross weight (W)
R01	Initial fuel weight
R02	Fuel weight
R03	Descent fuel (F_d)
R04	Drag count (D)
R05	Total distance
R06	Climb wind
	0.7 mach intercept altitude
	Cruise leg counter
	Temporary gross weight
R07	Cruise wind (V_W)
R08	Descent wind
	Remaining cruise distance
R09	Temperature deviation (E)
R09	θ

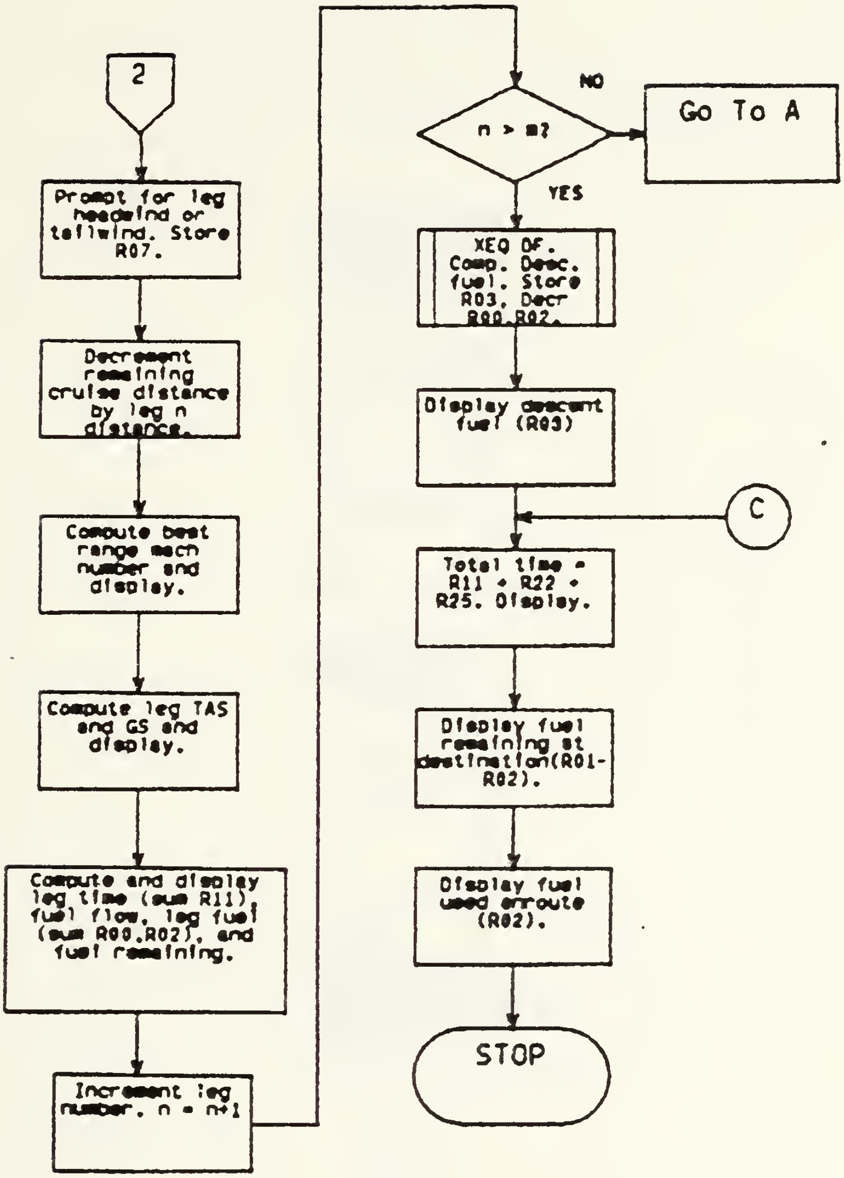
Register:	Contents:
R10	Optimum/cruise/peak altitude (A)
R11	Total time
R12	Climb distance (b, L_c, L_c')
R13	descent distance (c, L_d)
R14	W^2A
	Cruise leg DSE counter
R15	A^2D
R16	D^3
R17	E^3
R18	WA
	Average leg gross weight
R19	A^2W
R20	A^3
R21	Leg distance
R22	Descent time (t_d)
R23	Cruise specific fuel rate (F)
R24	Best range mach number (M)
	TAS
R25	Climb time (t_c, t_c')
R26	Climb fuel (F_c, F_c')

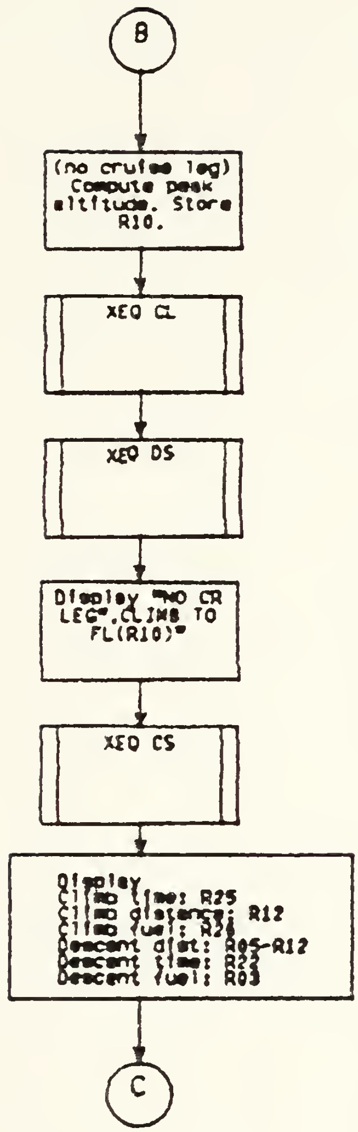
c. Program storage requirement is 236 registers, 1652 bytes.

CCD


START
Prompt for and input:
Fuel wt. into R01, R02, sum into R00
Stores wt. sum into R00
Drag count into R04
Total distance into R05
Climb wind vel. into R06
Descent wind vel. into R08
Temp. deviation into R09.
Prompt for STTO fuel and subtract from R00 and R02.
Compute optimum cruise altitude and display.
Prompt for desired cruise altitude and store in R10.
XEQ CL. Comp. climb dist,time,fuel. Store R12,R25,R26.
1


1
Compute approximate fuel rate at optimum altitude.
Subtract climb distance and approx descent distance from total distance to obtain approx cruise distance.
Use approximate fuel rate at optimum altitude and cruise destance to estimate weight.
XEQ DS. Computes descent time and distances.
Subtract computed climb and descent distances from total distance.
X<0?
NO
YES (no cruise leg)
Go to B
Display climb distance, climb time and climb fuel.
XEQ CS. Computes opt. climb CAS and mach.
Decrease GW (R00) and fuel wt (R02) by climb fuel.
Prompt for number of cruise legs m.
A
Display remaining cruise distance. Continue.
Prompt for cruise leg n distance.
Leg n dist > rem. cruise dist.?
YES
NO
2


2
Prompt for leg headwind or tailwind. Store R07.
Decrement remaining cruise distance by leg n distance.
Compute best range mach number and display.
Compute leg TAS and GS and display.
Compute and display leg time (sum R11), fuel flow, leg fuel (sum R00,R02), and fuel remaining.
Increment leg number. n = n+1
n > m?
NO
Go To A
YES
XEQ DF. Comp. Desc. fuel. Store R03, Decr R00,R02.
Display descent fuel (R03)
C
Total time = R11 + R22 + R25. Display.
Display fuel remaining at destination(R01-R02).
Display fuel used enroute (R02).
STOP


B
(no cruise leg)
Compute peak
altitude. Store
R10.
XEQ CL
XEQ DS
Display "NO CR
LEG".CLIMB TO
FL(R10)"
XEQ CS
Display
Climb time: R25
Climb distance: R12
Climb fuel:
Descent dist: R05-R12
Descent time:
Descent fuel: R03
C

5. PROGRAM LISTING

```
 01♦LBL "CCD
"
 02 FIX 0
 03 0
 04 "EMPTYWT
?"
 05 PROMPT
 06 STO 00
 07 "FUELWT?
"
 08 PROMPT
 09 ST+ 00
 10 STO 01
 11 STO 02
 12 "STOREWT
?"
 13 PROMPT
 14 ST+ 00
 15 "DRAG?"
 16 PROMPT
 17 STO 04
 18 "DIST?"
 19 PROMPT
 20 STO 05
 21 "CLWIND?
"
 22 PROMPT
 23 STO 06
 24 "DSWIND?
"
 25 PROMPT
 26 STO 08
 27 "T DEV?"
 28 PROMPT
 29 STO 09
 30 "STTO?"
 31 PROMPT
 32 ST- 02
 33 ST- 00
 34 1000
 35 ST/ 00
 36 ST/ 01
 37 ST/ 02
 38 55.27
 39 ENTER↑
 40 RCL 00
 41 .431
 42 *
 43 -
 44 RCL 00
 45 RCL 04
 46 X↑2
 47 *
 48 2772 E-9
 49 *
 50 -
 51 STO 10
 52 10
 53 *
 54 "OPT FL"
 55 ARCL X
 56 PROMPT
 57 "CRSE FL
?"
 58 PROMPT
 59 10
 60 /
 61 STO 10
 62 XEQ "CL"
 63 ST- 06
 64 25.7
 65 ENTER↑
 66 RCL 10
 67 .51
 68 *
 69 -
 70 RCL 04
 71 RCL 00
 72 *
 73 613 E-6
 74 *
 75 +
 76 RCL 18
 77 242 E-4
 78 *
 79 -
 80 RCL 14
 81 169 E-6
 82 *
 83 +
 84 RCL 19
 85 481 E-6
 86 *
 87 +
```

```
 88 STO 23
 89 RCL 05
 90 RCL 12
 91 -
 92 80
 93 -
 94 X<0?
 95 CLX
 96 *
 97 1000
 98 /
 99 ST- 06
100 RCL 00
101 ST+ 06
102 XEQ "DS"
103 CHS
104 RCL 05
105 +
106 RCL 12
107 -
108 X<0?
109 GTO 10
110 STO 03
111 BEEP
112 "CLDIST
"
113 ARCL 12
114 "⊢NM"
115 PROMPT
116 "CLTIME
"
117 ARCL 25
118 "⊢MIN"
119 PROMPT
120 FIX 1
121 "CLFUEL
"
122 ARCL 26
123 PROMPT
124 XEQ "CS"
125 RCL 26
126 ST- 00
127 ST- 02
128 1
129 STO 06
130 "N CR LE
GS?"
131 PROMPT
132 STO 14
133♦LBL 30
134 FIX 0
135 RCL 08
136 RND
137 "CRDIST
"
138 ARCL X
139 "⊢NM"
140 PROMPT
141 "LEG "
142 ARCL 06
143 "⊢ NM?"
144 PROMPT
145 STO 21
146 -
147 X<0?
148 GTO 30
149 "LEGWIND
?"
150 PROMPT
151 STO 07
152 RCL 00
153 STO 18
154 RCL 21
155 ST- 08
156 5 E-4
157 *
158 RCL 23
159 *
160 ST- 18
161 RCL 18
162 3 E-3
163 *
164 RCL 10
165 RCL 04
166 *
167 248 E-7
168 *
169 -
170 .345
171 +
172 RCL 15
173 367 E-9
174 *
175 +
176 RCL 10
177 X↑2
178 RCL 18
179 *
180 STO 19
181 848 E-8
182 *
183 +
```

```
184 RCL 20
185 RCL 18
186 X↑2
187 *
188 228 E-11
189 *
190 -
191 RCL 10
192 RCL 04
193 X↑2
194 *
195 RCL 18
196 *
197 227 E-12
198 *
199 +
200 STO 24
201 FIX 2
202 "LEG M="
203 ARCL X
204 PROMPT
205 RCL 10
206 36
207 -
208 X>0?
209 GTO 35
210 36
211 +
212 CHS
213 3.566
214 *
215 518.7
216 +
217 GTO 36
218◆LBL 35
219 390
220 ENTER↑
221◆LBL 36
222 RCL 09
223 1.8
224 *
225 +
226 SQRT
227 29.06
228 *
229 RCL 24
230 *
231 STO 24
232 FIX 0
233 "TAS="
234 ARCL X
235 PROMPT
236 RCL 07
237 -
238 "GS="
239 ARCL X
240 PROMPT
241 1/X
242 60
243 *
244 RCL 21
245 *
246 ST+ 11
247 "TIME "
248 ARCL X
249 "⊢MIN"
250 PROMPT
251 RCL 04
252 RCL 18
253 *
254 613 E-6
255 *
256 RCL 10
257 .5091
258 *
259 -
260 25.67
261 +
262 RCL 18
263 RCL 10
264 *
265 2418 E-5
266 *
267 -
268 RCL 18
269 X↑2
270 RCL 10
271 *
272 1693 E-7
273 *
274 +
275 RCL 19
276 4814 E-7
277 *
278 +
279 RCL 24
280 *
281 10
282 /
283 RND
284 10
285 *
```

```
286 "FF="
287 ARCL X
288 "⊢PPH"
289 PROMPT
290 RCL 24
291 /
292 RCL 21
293 *
294 1000
295 /
296 ST- 00
297 ST- 02
298 FIX 1
299 "LEGFUEL
="
300 ARCL X
301 PROMPT
302 "FUELQTY
="
303 ARCL 02
304 PROMPT
305 1
306 ST+ 06
307 DSE 14
308 GTO 30
309 FIX 0
310 "DS AT "
311 ARCL 13
312 "⊢NM"
313 PROMPT
314 "DSTIME
"
315 ARCL 22
316 "⊢MIN"
317 PROMPT
318 XEQ "DF"
319 "DSFUEL=
"
320 ARCL X
321 PROMPT
322 GTO 50
323◆LBL 10
324 RAD
325 RCL 10
326 6076
327 /
328 RCL 12
329 /
330 ATAN
331 STO 09
332 SIN
333 RCL 10
334 6076
335 /
336 RCL 13
337 /
338 ATAN
339 ST+ 09
340 SIN
341 *
342 6076
343 *
344 RCL 05
345 *
346 PI
347 ENTER↑
348 RCL 09
349 -
350 SIN
351 /
352 STO 10
353 XEQ "CL"
354 ST- 02
355 CHS
356 RCL 00
357 +
358 STO 06
359 XEQ "DS"
360 XEQ "DF"
361 BEEP
362 "NO CR L
EG"
363 AVIEW
364 PSE
365 RCL 10
366 10
367 *
368 FIX 0
369 "CL TO F
L"
370 ARCL X
371 PROMPT
372 XEQ "CS"
373 "CLTIME
"
374 ARCL 25
375 "⊢MIN"
376 PROMPT
377 RCL 12
378 ST- 05
379 "CLDIST
"
```

```
ARCL X
"⊢NM"
PROMPT
FIX 1
"CLFUEL "
ARCL 26
PROMPT
FIX 0
"DSTIME "
ARCL 22
"⊢MIN"
PROMPT
"DSDIST "
ARCL 05
"⊢NM"
PROMPT
FIX 1
"DSFUEL "
ARCL 03
PROMPT
◆LBL 50
FIX 0
"ΣTIME "
ARCL 11
"⊢MIN"
PROMPT
FIX 1
RCL 01
RCL 02
"DESTFUEL "
ARCL X
PROMPT
-
"ΣFUEL="
ARCL X
PROMPT
GTO "CCD"
RTN
◆LBL "CL"
RCL 00
X↑2
*
STO 14
432 E-7
*
7.65
+
RCL 04
663 E-5
*
+
RCL 00
.111
*
-
RCL 10
483 E-4
*
-
RCL 10
X↑2
RCL 04
*
STO 15
181 E-8
*
-
RCL 04
3
Y↑X
STO 16
469 E-10
*
-
E↑X
STO 12
1.03
*
1.88
-
RCL 09
.956
*
-
RCL 09
RCL 12
*
441 E-4
*
+
RCL 09
X↑2
RCL 12
*
982 E-6
*
```

```
+
RCL 09
3
Y↑X
865 E-6
*
+
STO 12
RCL 04
376 E-5
*
569 E-4
-
RCL 00
385 E-4
*
-
RCL 00
RCL 10
*
STO 18
627 E-5
*
+
RCL 14
159 E-7
*
-
RCL 10
X↑2
RCL 00
*
STO 19
987 E-7
*
-
RCL 16
186 E-10
*
-
RCL 10
3
Y↑X
STO 20
156 E-7
*
+
E↑X
STO 25
.5
*
1.405
+
RCL 09
X↑2
442 E-5
*
-
RCL 25
X↑2
33 E-3
*
+
RCL 09
X↑2
RCL 25
*
145 E-5
*
+
RCL 09
RCL 25
X↑2
*
268 E-5
*
+
RCL 17
123 E-6
*
+
STO 25
STO 11
60
/
RCL 06
*
ST- 12
7.94
ENTER↑
RCL 04
.07
*
-
RCL 10
RCL 00
X↑2
*
873 E-7
*
+
RCL 10
```

```
578 RCL 04
579 *
580 RCL 00
581 *
582 869 E-7
583 *
584 +
585 STO 26
586 96.7
587 *
588 RCL 09
589 4.76
590 *
591 -
592 3
593 -
594 RCL 09
595 RCL 26
596 *
597 .954
598 *
599 +
600 RCL 09
601 X↑2
602 RCL 26
603 *
604 295 E-4
605 *
606 +
607 RCL 09
608 RCL 26
609 X↑2
610 *
611 392 E-4
612 *
613 +
614 RCL 17
615 129 E-4
616 *
617 +
618 RCL 26
619 3
620 Y↑X
621 144 E-4
622 *
623 +
624 1000
625 /
626 STO 26
627 RTN
628◆LBL "DS"
629 RCL 16
630 405 E-14
631 *
632 RCL 04
633 RCL 06
634 *
635 168 E-10
636 *
637 -
638 235 E-6
639 +
640 RCL 20
641 *
642 7.13
643 +
644 STO 22
645 ST+ 11
646 RCL 10
647 3.59
648 *
649 31
650 -
651 RCL 16
652 RCL 10
653 *
654 RCL 06
655 *
656 894 E-12
657 *
658 -
659 RCL 20
660 RCL 04
661 *
662 RCL 06
663 *
664 167 E-9
665 *
666 -
667 RCL 15
668 RCL 04
669 *
670 RCL 06
671 *
672 151 E-10
673 *
674 +
675 RCL 22
676 RCL 08
677 *
678 60
679 /
```

```
680 -
681 STO 13
682 RTN
683◆LBL "CS"
684 RCL 04
685 .4
686 *
687 CHS
688 320
689 +
690 FIX 0
691 "CL AT"
692 ARCL X
693 "⊢KCAS"
694 PROMPT
695 RCL 04
696 239 E-5
697 *
698 E↑X
699 19.7
700 *
701 STO 06
702 RCL 10
703 -
704 X>0?
705 RTN
706 10
707 ST* 06
708 ".7M AT
FL"
709 ARCL 06
710 PROMPT
711 RTN
712◆LBL "DF"
713 RCL 10
714 FIX 1
715 .002
716 *
717 .03
718 +
719 RCL 00
720 30
721 -
722 *
723 CHS
724 RCL 10
725 .715
726 Y↑X
727 .723
728 *
729 +
730 RCL 04
731 -1.63 E-
3
732 *
733 E↑X
734 *
735 .049
736 *
737 ST- 00
738 ST- 02
739 STO 03
740 END
```

DRAG - DRAG COUNT AND EXTERNAL STORES WEIGHT

1. EQUATIONS

No equations are used in this program. The user indicates the type of store to be loaded. The program then selects an appropriate store subroutine which calculates the drag count and stores weight for the station(s). Stations one and five and stations two and four are grouped together. In order for the store subroutine to correctly calculate drag count and weight, it must know the rack type and which rack positions are loaded. The subroutine "MTA" determines the type of rack loaded on each station and sets appropriate flags to indicate rack type to the store subroutine. If a MER or TER is loaded, the program prompts for the rack configuration, receiving inputs from the user defined keys. A rack configuration code is assigned based on these inputs and is used by the store subroutine to assign a station drag count. Table DRAG-1 summarizes the possible station configuration codes which will be stored in R05 by the routine.

2. PROGRAMS AND SUBROUTINES USED

"MTA" - Computes rack type and rack configuration code.

"ST" - Utility.

"SP" - Utility.

"S2" - Utility.

"S3" - Utility.

Code:	Configuration:	
0	AERO-7A/AERO-7B	
	(fwd) (aft)	
1		Empty TER
2		Empty MER
3		TER
4		MER
4		TER
5		TER
5		MER
5		MER
6		MER
8		MER
9		MER
10		MER

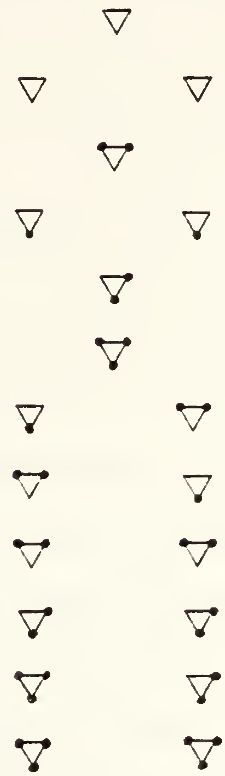


Table DRAG - 1

3. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS.

a. Flags used:

Flag:	Meaning When Set:
01	Current stations are 1 and 5.
02	Current stations are 2 and 4.
03	Current station is 3.
04	Conical tail bomb

Flag:	Meaning When Set:
05	MER
06	TER
07	AERO-7
08	Empty TER
09	Empty MER
10	Training store

b. Data storage registers.

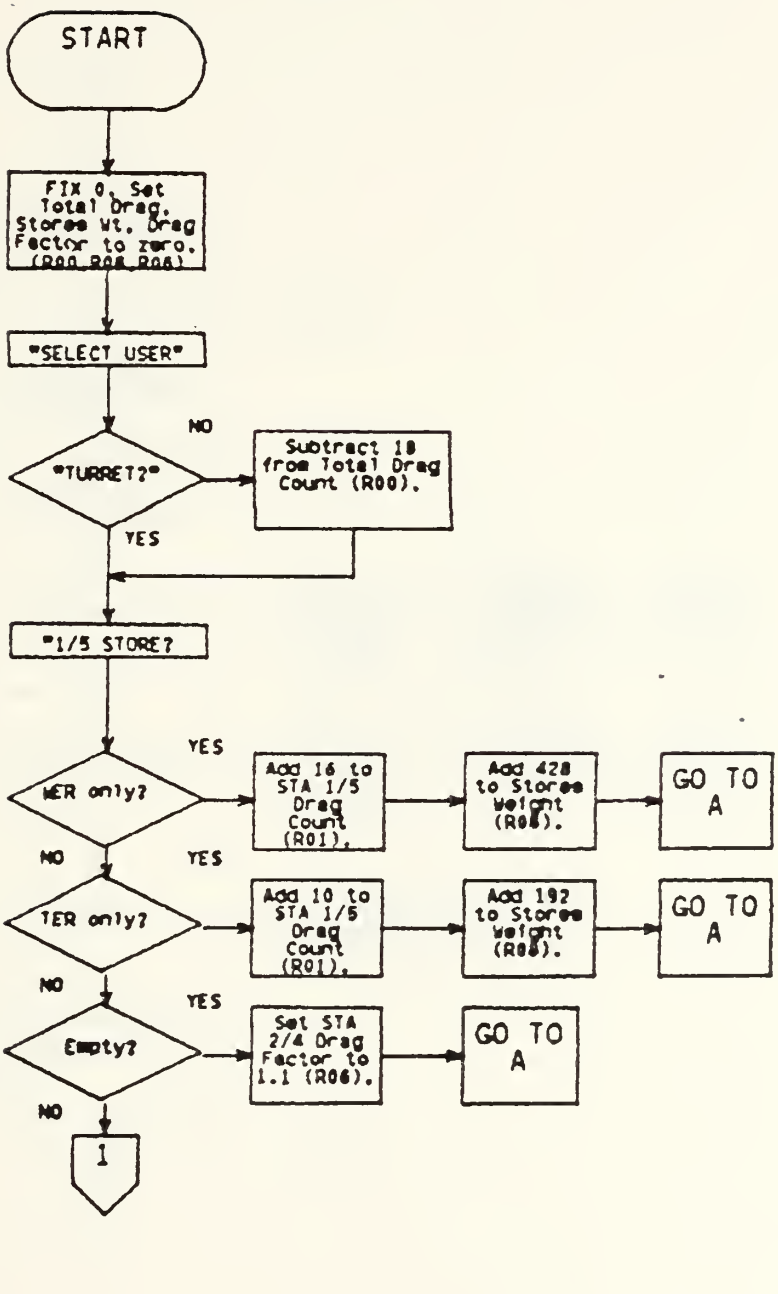
Register:	Contents:
R00	Total drag count
R01	Stations 1 and 5 drag count
R02	Stations 2 and 4 drag count
R03	Station 3 drag count
R04	Station type 1=1/5; 2=2/4; 3=3
R05	Rack configuration code
R06	Empty inboard (0.7) or empty outboard (1.1) stations drag factor.
R07	Temporary storage - numeric store type
R08	Stores weight
R09	Return loop indirect address register
R10	Stations 1 and 5 drag factor (1 or 0.7)
R11	Stations 2 and 4 drag factor (1 or 1.1)
R12	Temporary stores weight register
R13	Temproary storage
R14	Alternate weight storage register (used by training store routines)

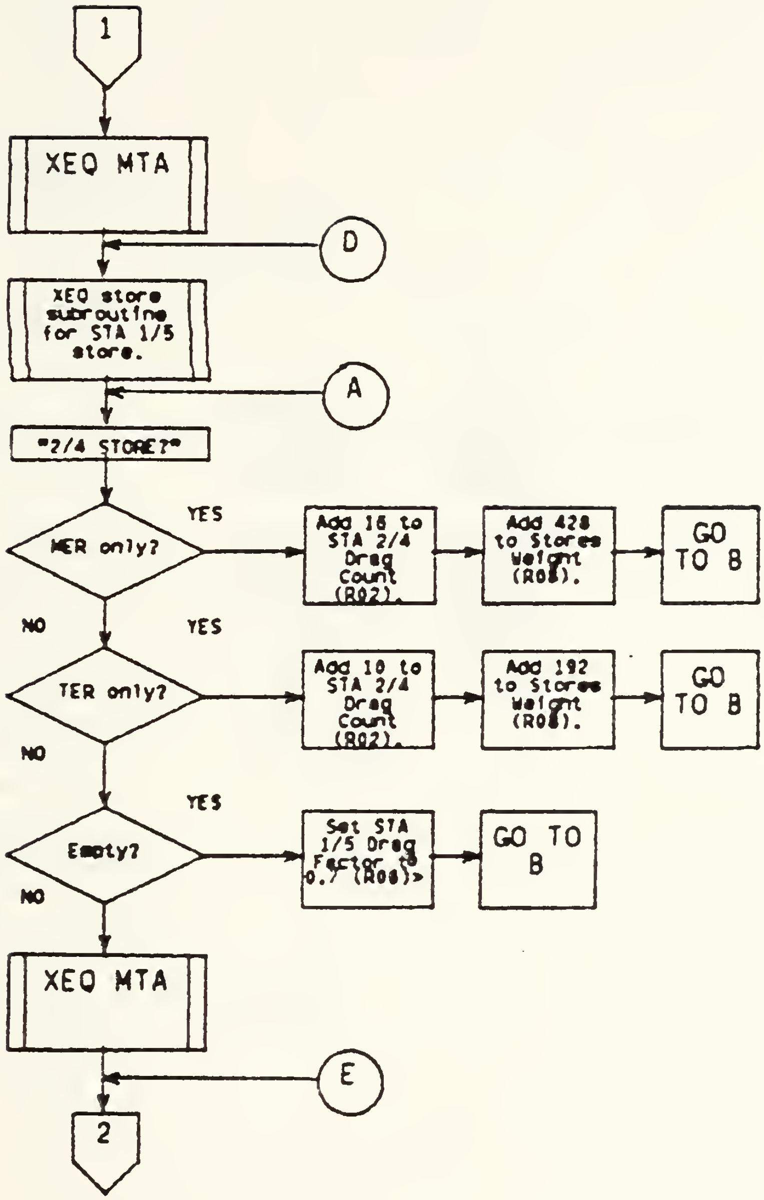
c. Program storage requirement is 249 registers, 1737 bytes.

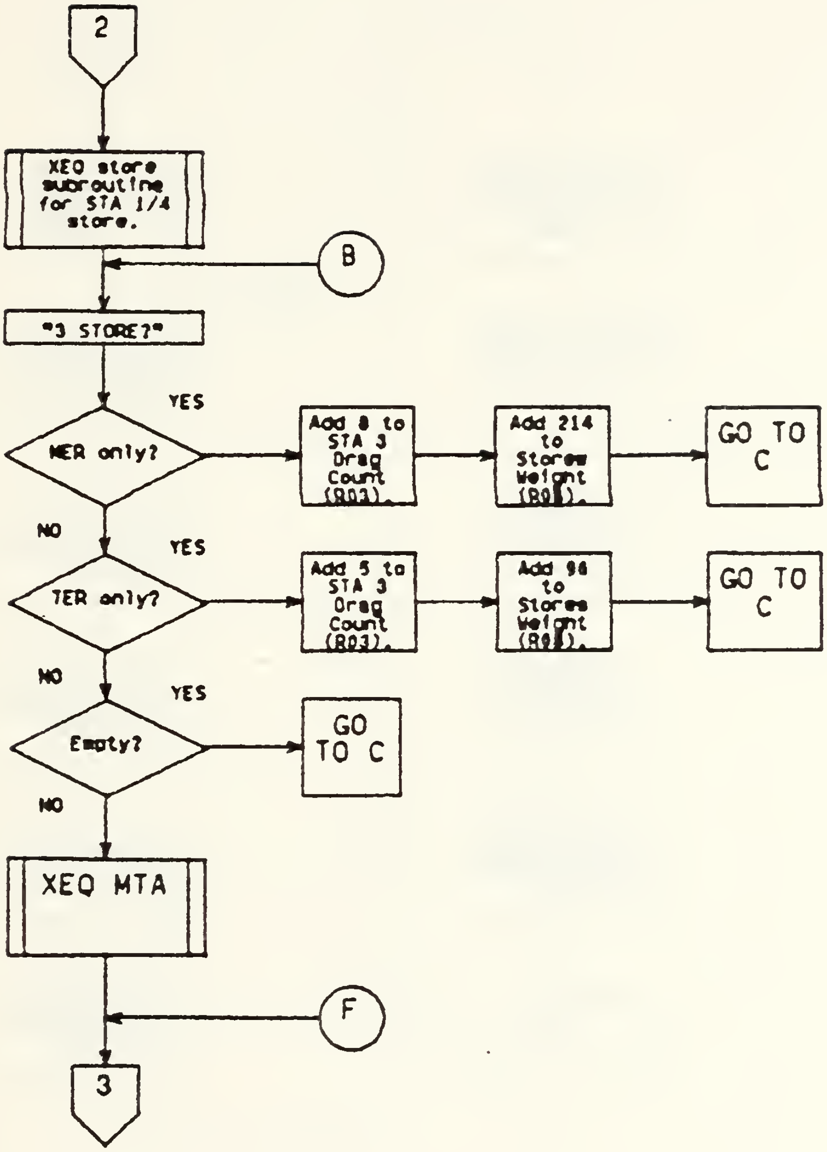
4. FLOWCHART

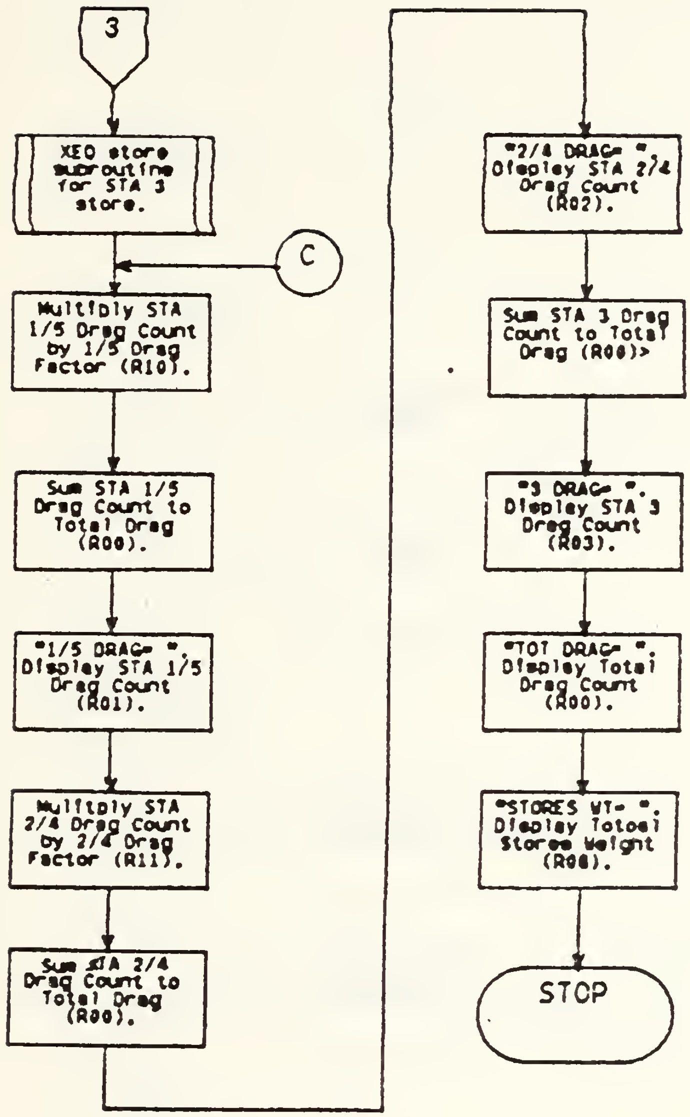
See following page.

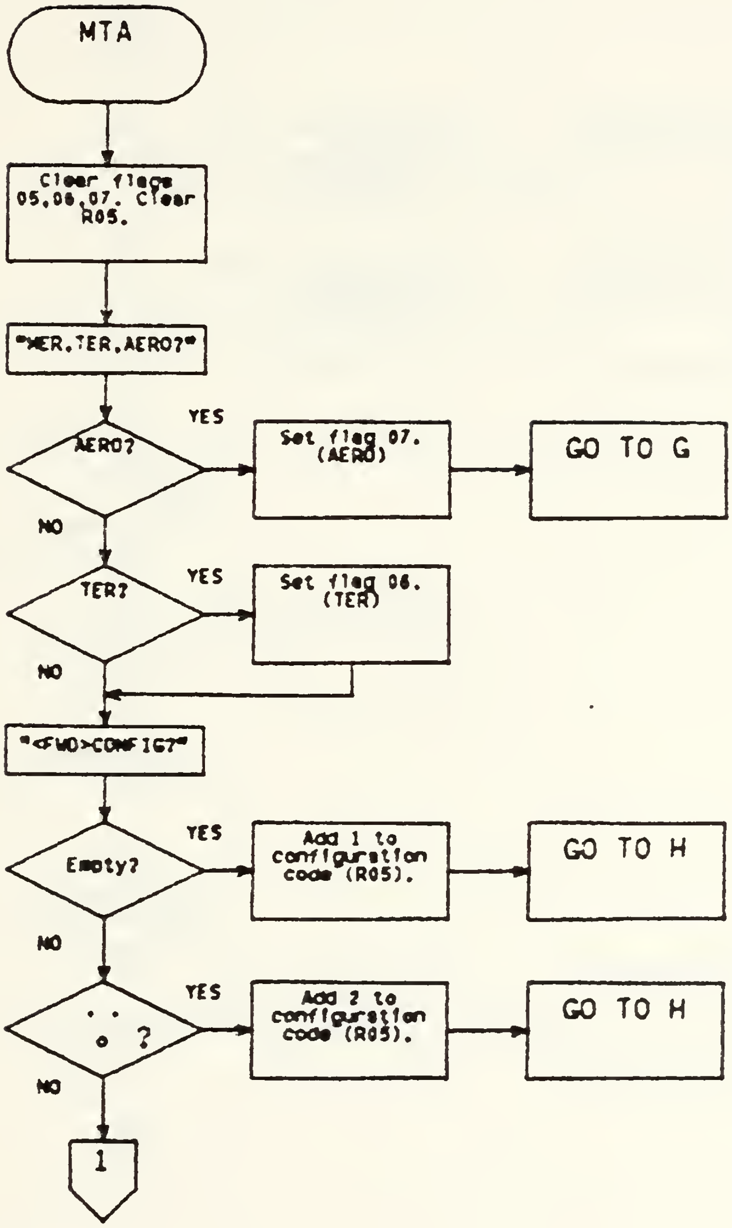
DRAG

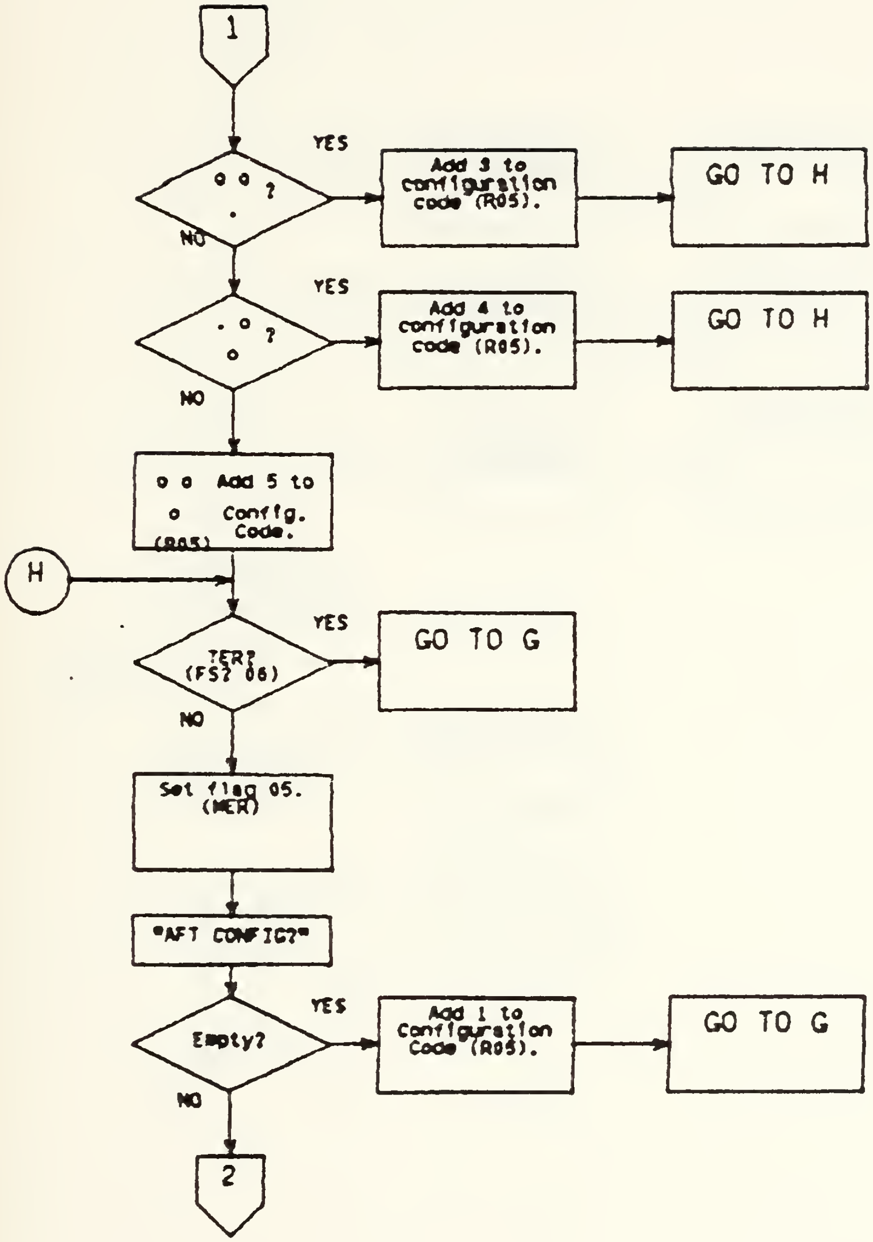

START
FIX 0. Set Total Drag, Stores Wt, Drag Factor to zero. (R00,R08,R06)
"SELECT USER"
"TURRET?"
NO
YES
Subtract 18 from Total Drag Count (R00).
"1/5 STORE?
MER only?
YES
NO
Add 16 to STA 1/5 Drag Count (R01).
Add 428 to Stores Weight (R08).
GO TO A
TER only?
Add 10 to STA 1/5 Drag Count (R01).
Add 192 to Stores Weight (R08).
GO TO A
Empty?
Set STA 2/4 Drag Factor to 1.1 (R06).
GO TO A
1

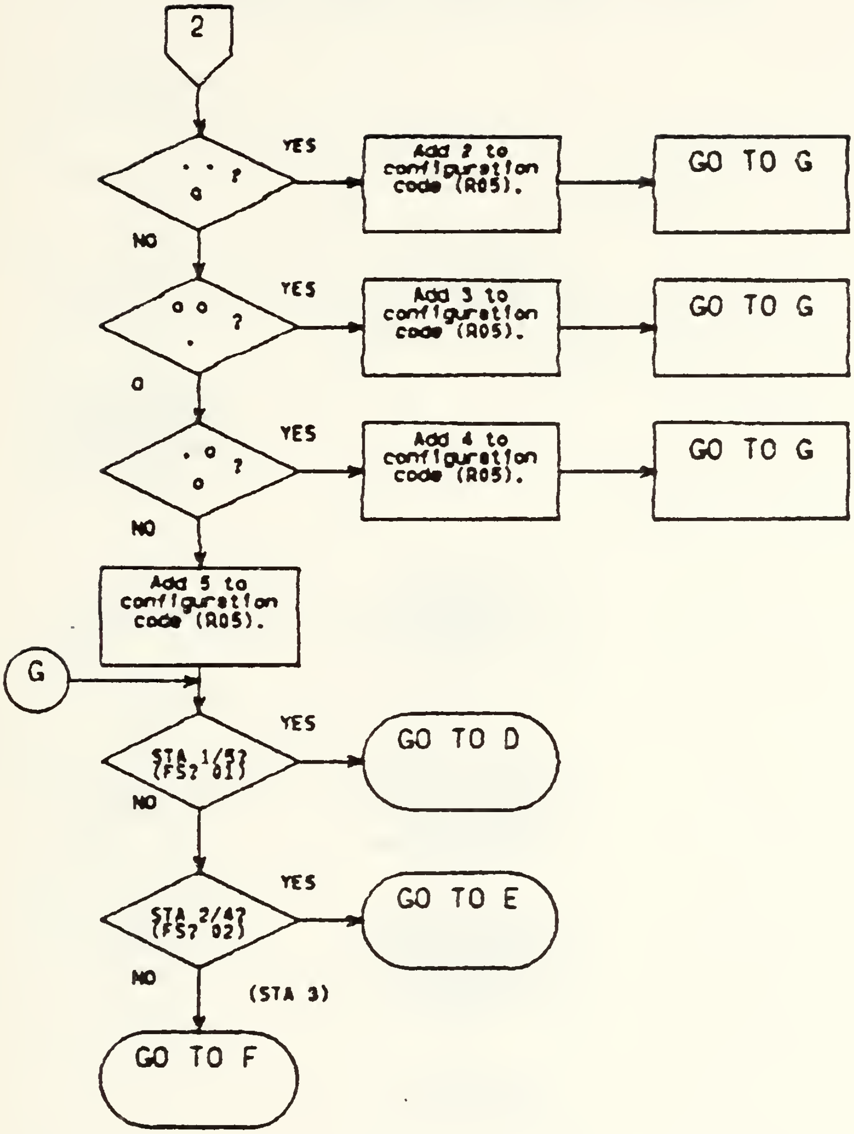

1
XEQ MTA
D
XEQ store subroutine for STA 1/5 store.
A
"2/4 STORE?"
MER only?
YES
Add 16 to STA 2/4 Drag Count (R02).
Add 428 to Stores Weight (R08).
GO TO B
NO
TER only?
YES
Add 10 to STA 2/4 Drag Count (R02).
Add 192 to Stores Weight (R08).
GO TO B
NO
Empty?
YES
Set STA 1/5 Drag Factor to 0.7 (R08)>
GO TO B
NO
XEQ MTA
E
2


2
XEQ store subroutine for STA 1/4 store.
B
"3 STORE?"
YES
MER only?
Add 8 to STA 3 Drag Count (R03).
Add 214 to Stores Weight
GO TO C
NO
YES
TER only?
Add 5 to STA 3 Drag Count (R03).
Add 98 to Stores Weight
GO TO C
NO
YES
Empty?
GO TO C
NO
XEQ MTA
F
3

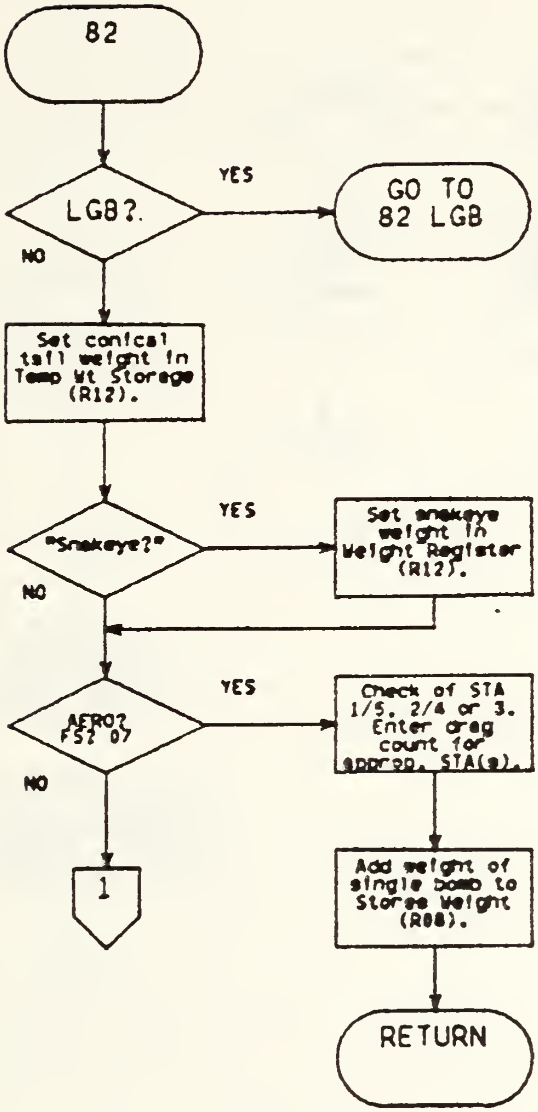

3
XEQ store subroutine for STA 3 store.
C
Multiply STA 1/5 Drag Count by 1/5 Drag Factor (R10).
Sum STA 1/5 Drag Count to Total Drag (R00).
"1/5 DRAG= ". Display STA 1/5 Drag Count (R01).
Multiply STA 2/4 Drag Count by 2/4 Drag Factor (R11).
Sum STA 2/4 Drag Count to Total Drag (R00).
"2/4 DRAG= ". Display STA 2/4 Drag Count (R02).
Sum STA 3 Drag Count to Total Drag (R00)>
"3 DRAG= ". Display STA 3 Drag Count (R03).
"TOT DRAG= ". Display Total Drag Count (R00).
"STORES WT= ". Display Total Stores Weight (R08).
STOP

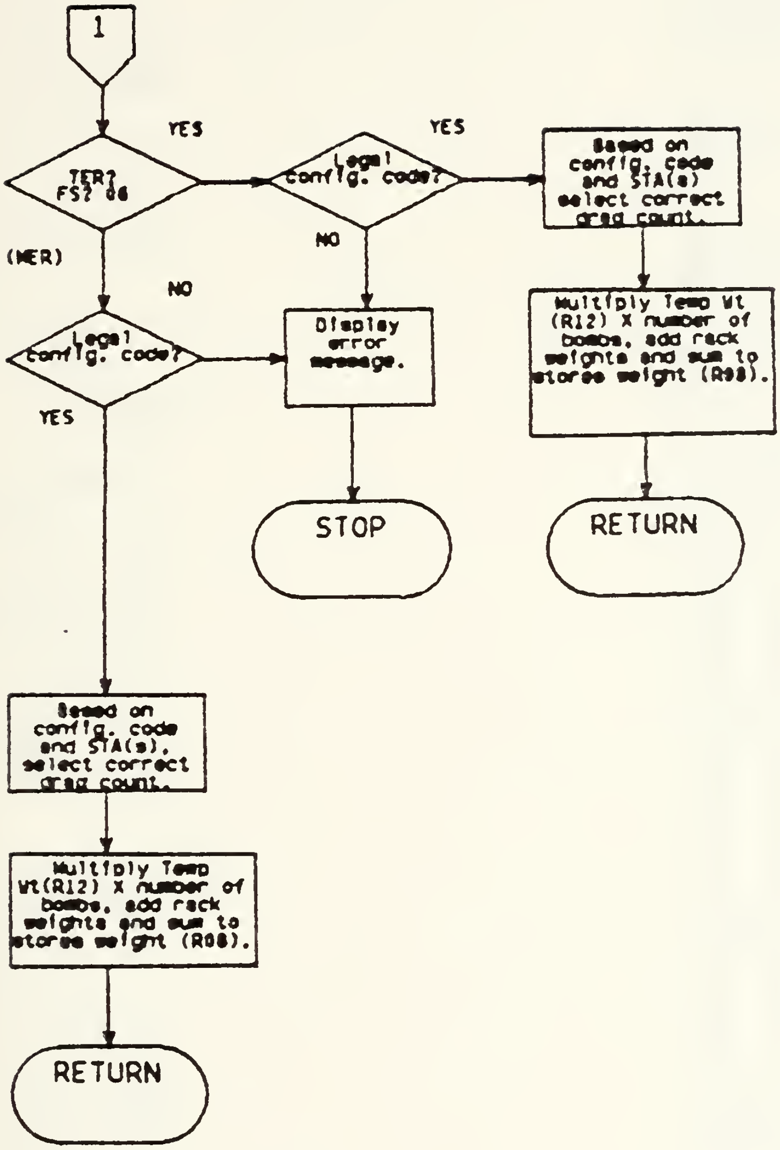

MTA
Clear flags 05,06,07. Clear R05.
"MER,TER,AERO?"
AERO?
YES
Set flag 07. (AERO)
GO TO G
NO
TER?
YES
Set flag 06. (TER)
NO
"<FWD>CONFIG?"
Empty?
YES
Add 1 to configuration code (R05).
GO TO H
NO
YES
Add 2 to configuration code (R05).
GO TO H
NO
1


1
YES
o o ?
.
NO
Add 3 to configuration code (R05).
GO TO H
YES
. o ?
o
NO
Add 4 to configuration code (R05).
GO TO H
o o Add 5 to
o Config. Code.
(R05)
H
YES
TER? (FS? 06)
NO
GO TO G
Set flag 05. (MER)
"AFT CONFIG?"
YES
Empty?
NO
Add 1 to Configuration Code (R05).
GO TO G
2


2
YES
Add 2 to configuration code (R05).
GO TO G
NO
YES
Add 3 to configuration code (R05).
GO TO G
YES
Add 4 to configuration code (R05).
GO TO G
NO
Add 5 to configuration code (R05).
G
YES
STA 1/5?
(FS? 01)
GO TO D
NO
YES
STA 2/4?
(FS? 02)
GO TO E
NO
(STA 3)
GO TO F

TYPICAL STORE SUBROUTINE (MK 82)




1
TER?
FS? 06
YES
(MER)
NO
Legal
config. code?
YES
NO
Based on
config. code
and STA(s)
select correct
drag count.
Multiply Temp Wt
(R12) X number of
bombs, add rack
weights and sum to
stores weight (R08).
Display
error
message.
STOP
RETURN
Based on
config. code
and STA(s),
select correct
drag count.
Multiply Temp
Wt(R12) X number of
bombs, add rack
weights and sum to
stores weight (R08).
RETURN

5. PROGRAM LISTING

```
 01◆LBL "DRA
G"
 02 FIX 0
 03 0
 04 STO 00
 05 STO 08
 06 1
 07 STO 10
 08 STO 11
 09 CF 10
 10 "SELECT
USER"
 11 AON
 12 PSE
 13 AOFF
 14 "TURRET?
"
 15 PROMPT
 16◆LBL A
 17 18
 18 STO 00
 19◆LBL B
 20 CF 02
 21 CF 03
 22 SF 01
 23 99
 24 STO 09
 25 "1/5 STO
RE?"
 26 PROMPT
 27 STO 07
 28 GTO 96
 29◆LBL F
 30 1.1
 31 STO 11
 32 0
 33 STO 01
 34 GTO 99
 35◆LBL C
 36 16
 37 STO 01
 38 428
 39 ST+ 08
 40 GTO 99
 41◆LBL D
 42 10
 43 STO 01
 44 192
 45 ST+ 08
 46 GTO 99
 47◆LBL 96
 48 GTO "MTA
"
 49◆LBL 93
 50 GTO IND
07
 51◆LBL 99
 52 CF 01
 53 SF 02
 54 98
 55 STO 09
 56 "2/4 STO
RE?"
 57 PROMPT
 58 STO 07
 59 GTO 95
 60◆LBL F
 61 .7
 62 STO 10
 63 0
 64 STO 02
 65 GTO 98
 66◆LBL C
 67 16
 68 STO 02
 69 428
 70 ST+ 08
 71 GTO 98
 72◆LBL D
 73 10
 74 STO 02
 75 192
 76 ST+ 08
 77 GTO 98
 78◆LBL 95
 79 XEQ "MTA
"
 80◆LBL 92
 81 GTO IND
07
 82◆LBL 98
 83 CF 02
 84 SF 03
 85 97
```

```
 86 STO 09
 87 "3 STORE
?"
 88 PROMPT
 89 STO 07
 90 GTO 94
 91◆LBL F
 92 0
 93 STO 03
 94 GTO 97
 95◆LBL C
 96 8
 97 STO 03
 98 214
 99 ST+ 08
100 GTO 97
101◆LBL D
102 5
103 STO 03
104 96
105 ST+ 08
106 GTO 97
107◆LBL 94
108 XEQ "MTA
"
109◆LBL 91
110 GTO IND
07
111◆LBL 97
112 RCL 01
113 RCL 10
114 *
115 ST+ 00
116 "1/5 DRA
G="
117 ARCL X
118 AVIEW
119 STOP
120 RCL 02
121 RCL 11
122 *
123 ST+ 00
124 "2/4 DRA
G="
125 ARCL X
126 AVIEW
127 STOP
128 RCL 03
129 ST+ 00
130 "3 DRAG=
"
131 ARCL X
132 AVIEW
133 STOP
134 RCL 00
135 "TOT DRA
G="
136 ARCL X
137 AVIEW
138 STOP
139 RCL 08
140 "STORES
WT="
141 ARCL X
142 AVIEW
143 STOP
144 GTO "DRA
G"
145◆LBL "MTA
"
146 0
147 STO 05
148 CF 05
149 CF 06
150 CF 07
151 "MER/TER
/AERO?"
152 PROMPT
153◆LBL E
154 SF 07
155 GTO 02
156◆LBL D
157 SF 06
158◆LBL C
159 "<FWD> C
ONFIG?"
160 PROMPT
161◆LBL F
162 1
163 STO 05
164 GTO 01
165◆LBL G
166 2
167 STO 05
168 GTO 01
169◆LBL H
170 3
171 STO 05
172 GTO 01
173◆LBL I
174 4
175 STO 05
```

```
176 GTO 01
177◆LBL J
178 5
179 STO 05
180◆LBL 01
181 FS? 06
182 GTO 02
183 SF 05
184 "AFT CON
FIG"
185 PROMPT
186◆LBL F
187 1
188 ST+ 05
189 GTO 02
190◆LBL G
191 2
192 ST+ 05
193 GTO 02
194◆LBL H
195 3
196 ST+ 05
197 GTO 02
198◆LBL I
199 4
200 ST+ 05
201 GTO 02
202◆LBL J
203 5
204 ST+ 05
205◆LBL 02
206 FS? 01
207 GTO 93
208 FS? 02
209 GTO 92
210 GTO 91
211 GTO 87
212◆LBL 81
213 SF 04
214 260
215 STO 12
216 "SNAKEYE
?"
217 PROMPT
218◆LBL A
219 301
220 STO 12
221 CF 04
222◆LBL B
223 GTO IND
05
224◆LBL 00
225 10
226 ENTER↑
227 FS? 04
228 6
229 ENTER↑
230 XEQ "ST"
231 XEQ "S2"
232 2
233 *
234 XEQ "S3"
235 STO 14
236 ST+ 08
237 GTO 21
238◆LBL 04
239 FS? 03
240 GTO 89
241 36
242 ENTER↑
243 FS? 04
244 28
245 ENTER↑
246 XEQ "ST"
247 RCL 12
248 4
249 *
250 STO 14
251 192
252 +
253 ST+ 08
254 GTO 21
255◆LBL 05
256 46
257 ENTER↑
258 FS? 04
259 36
260 ENTER↑
261 XEQ "ST"
262 XEQ "S2"
263 6
264 *
265 STO 14
266 192
267 +
268 XEQ "S3"
269 ST+ 08
270 GTO 21
271◆LBL 08
272 56
273 ENTER↑
274 FS? 04
```

```
275 44
276 ENTER↑
277 FS? 03
278 GTO 89
279 XEQ "S3"
280 RCL 12
281 8
282 *
283 STO 14
284 428
285 +
286 ST+ 08
287 GTO 21
288◆LBL 09
289 FS? 01
290 GTO 89
291 FS? 03
292 GTO 89
293 66
294 ENTER↑
295 FS? 04
296 50
297 ENTER↑
298 STO 02
299 RCL 12
300 10
301 *
302 STO 14
303 428
304 +
305 ST+ 08
306 GTO 21
307◆LBL 10
308 FS? 02
309 GTO 89
310 72
311 ENTER↑
312 FS? 04
313 54
314 ENTER↑
315 FS? 01
316 STO 01
317 XEQ "S3"
318 12
319 *
320 STO 14
321 428
322 +
323 XEQ "S3"
324 ST+ 08
325 GTO 21
326◆LBL 21
327 FS? 10
328 GTO IND
13
329 GTO IND
09
330◆LBL 89
331 BEEP
332 "NON-STD
 LOAD"
333 PROMPT
334 GTO "DRA
G"
335◆LBL 76
336 740
337 STO 12
338 52
339 ENTER↑
340 XEQ "ST"
341 XEQ "S2"
342 XEQ "S3"
343 ST+ 08
344 GTO 21
345◆LBL 82
346 "LGB?"
347 PROMPT
348◆LBL A
349 GTO 22
350◆LBL B
351 SF 04
352 531
353 STO 12
354 "SNAKEYE
?"
355 PROMPT
356◆LBL A
357 572
358 STO 12
359 CF 04
360◆LBL B
361 GTO IND
05
362◆LBL 00
363 11
364 ENTER↑
365 FS? 04
366 7
367 ENTER↑
368 XEQ "ST"
369 6
370 ENTER↑
```

```
FS? 04
3
ENTER↑
FS? 03
STO 03
RCL 12
2
*
XEQ "S3"
ST+ 08
STO 14
GTO 21
♦LBL 04
FS? 03
GTO 89
41
ENTER↑
FS? 04
31
ENTER↑
XEQ "ST"
RCL 12
4
*
STO 14
192
+
ST+ 08
GTO 21
♦LBL 05
60
ENTER↑
FS? 06
54
ENTER↑
FS? 04
38
ENTER↑
XEQ "ST"
XEQ "S2"
6
*
STO 14
192
+
FS? 06
136
FS? 06
+
XEQ "S3"
ST+ 08
GTO 21
♦LBL 08
60
ENTER↑
FS? 04
46
ENTER↑
FS? 03
GTO 89
XEQ "ST"
RCL 12
8
*
STO 14
428
+
ST+ 08
GTO 21
♦LBL 09
FS? 01
GTO 89
FS? 03
GTO 89
74
ENTER↑
FS? 04
54
ENTER↑
STO 02
RCL 12
10
*
STO 14
428
+
ST+ 08
GTO 21
♦LBL 10
FS? 02
GTO 89
80
ENTER↑
FS? 04
58
ENTER↑
FS? 01
STO 01
XEQ "S2"
12
*
STO 14
```

```
473 428
474 +
475 XEQ "S3"
476 ST+ 08
477 GTO 21
478♦LBL A
479 RCL 05
480 2
481 -
482 X>0?
483 GTO 89
484 34
485 ENTER↑
486 FS? 07
487 18
488 ENTER↑
489 FS? 05
490 GTO 89
491 XEQ "ST"
492 17
493 ENTER↑
494 FS? 03
495 STO 03
496 1202
497 ENTER↑
498 FS? 06
499 1394
500 ENTER↑
501 FS? 03
502 XEQ "S3"
503 ST+ 08
504 GTO 21
505♦LBL 83
506 "LGB?"
507 PROMPT
508♦LBL B
509 FS? 05
510 11
511 STO 05
512 GTO IND
05
513♦LBL 00
514 8
515 ENTER↑
516 XEQ "ST"
517 XEQ "S2"
518 1970
519 ENTER↑
520 XEQ "S3"
521 ST+ 08
522 STO 14
523 GTO 21
524♦LBL 04
525 FS? 03
526 GTO 89
527 16
528 ENTER↑
529 XEQ "ST"
530 3940
531 STO 14
532 192
533 +
534 ST+ 08
535 GTO 21
536♦LBL 05
537 FS? 02
538 GTO 89
539 44
540 ENTER↑
541 FS? 01
542 STO 01
543 XEQ "S2"
544 5910
545 ENTER↑
546 XEQ "S3"
547 STO 14
548 192
549 +
550 ST+ 08
551 GTO 21
552♦LBL 11
553 52
554 ENTER↑
555 XEQ "ST"
556 XEQ "S2"
557 5910
558 ENTER↑
559 XEQ "S3"
560 STO 14
561 428
562 +
563 ST+ 08
564 GTO 21
565♦LBL A
566 RCL 05
567 2
568 -
569 X>0?
570 GTO 89
571 46
572 ENTER↑
573 FS? 07
```

```
574 28
575 ENTER↑
576 FS? 05
577 GTO 89
578 XEQ "ST"
579 23
580 ENTER↑
581 FS? 03
582 STO 03
583 2200
584 ENTER↑
585 FS? 06
586 2392
587 ENTER↑
588 XEQ "S3"
589 ST+ 08
590 GTO 21
591♦LBL 86
592 SF 10
593 68
594 STO 13
595 GTO 81
596♦LBL 68
597 RCL 14
598 .1654
599 GTO "SP"
600♦LBL 87
601 SF 10
602 78
603 STO 13
604 GTO 82
605♦LBL 78
606 RCL 14
607 .3729
608 GTO "SP"
609♦LBL 88
610 SF 10
611 28
612 STO 13
613 GTO 83
614♦LBL 28
615 RCL 14
616 .2051
617 GTO "SP"
618♦LBL 84
619 "LGB?"
620 PROMPT
621♦LBL B
622 FS? 05
623 GTO 89
624 FS? 06
625 GTO 89
626 11
627 ENTER↑
628 XEQ "ST"
629 2
630 /
631 FS? 03
632 STO 03
633 2005
634 ST+ 08
635 GTO 21
636♦LBL A
637 FS? 03
638 GTO 89
639 44
640 ENTER↑
641 XEQ "ST"
642 4260
643 ST+ 08
644 GTO 21
645♦LBL 01
646 20
647 ENTER↑
648 XEQ "ST"
649 XEQ "S2"
650 4476
651 ENTER↑
652 XEQ "S3"
653 ST+ 08
654 GTO 21
655♦LBL 58
656 FS? 06
657 GTO 89
658 FS? 07
659 GTO 89
660 67
661 ENTER↑
662 XEQ "ST"
663 XEQ "S2"
664 584
665 ENTER↑
666 XEQ "S3"
667 ST+ 08
668 GTO 21
669♦LBL 41
670 GTO 84
671♦LBL 45
672 28
673 STO 12
674 GTO IND
05
```

```
◆LBL 05
45
ENTER↑
XEQ "ST"
XEQ "S2"
6
*
192
+
XEQ "S3"
ST+ 08
GTO 21
◆LBL 10
68
ENTER↑
XEQ "ST"
XEQ "S2"
12
*
48
+
XEQ "S3"
ST+ 08
GTO 21
◆LBL 56
136
ENTER↑
XEQ "ST"
XEQ "S2"
4430
ENTER↑
XEQ "S3"
ST+ 08
GTO 21
◆LBL 52
90
ENTER↑
XEQ "ST"
XEQ "S2"
2486
ENTER↑
XEQ "S3"
ST+ 08
GTO 21
◆LBL 55
126
ENTER↑
XEQ "ST"
XEQ "S2"
4388
ENTER↑
XEQ "S3"
ST+ 08
GTO 21
◆LBL 25
116
ENTER↑
XEQ "ST"
XEQ "S2"
4264
ENTER↑
XEQ "S3"
ST+ 08
GTO 21
◆LBL 36
88
ENTER↑
XEQ "ST"
XEQ "S2"
2516
ENTER↑
XEQ "S3"
ST+ 08
GTO 21
ENTER↑
◆LBL "ST"
FS? 01
STO 01
FS? 02
STO 02
RTN
◆LBL "S3"
FS? 03
2
FS? 03
/
RTN
◆LBL "SP"
*
ST- 08
CF 10
GTO 21
◆LBL "S2"
2
/
FS? 03
STO 03
RCL 12
.END.
```

LAA - LANDING AND APPROACH SPEEDS

1. EQUATIONS

$V_s = 48.25 + 1.375W$

$V_{sw} = 1.09V_s$

$V_{mld} = 1.18V_s$

$V_{app} = 1.28V_s$

V_s = power approach stall speed [KCAS]

W = gross weight [pounds/1000]

V_{sw} = stall warning speed [KCAS]

V_{mld} = minimum landing distance approach speed [KCAS]

V_{app} = optimum approach speed [KCAS]

2. FLOWCHART

See following page.

3. PROGRAMS AND SUBROUTINES USED

None.

4. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS

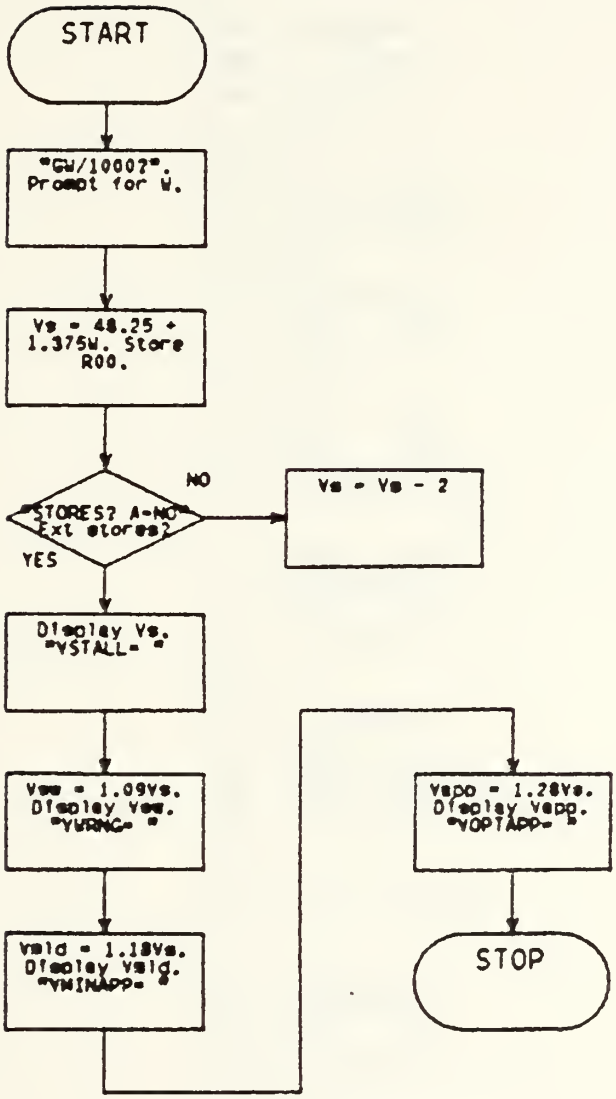
a. Flags used: none

b. Data storage registers.

Register:	Contents:
R00	Power approach stall speed (V_s)

c. Program storage requirement is 18 registers, 124 bytes.

LAA


START
"GW/1000?". Prompt for W.
Vs = 48.25 + 1.375W. Store R00.
"STORES? A-NO" Ext stores?
NO
Vs = Vs - 2
YES
Display Vs. "VSTALL= "
Vsw = 1.09Vs. Display Vsw. "VWRNG= "
Vsld = 1.18Vs. Display Vsld. "VMINAPP= "
Vapp = 1.28Vs. Display Vapp. "VOPTAPP= "
STOP

5. PROGRAM LISTING

```
♦LBL "LAA"
FIX 0
"GW/1000?"
PROMPT
1.375
*
48.25
+
STO 00
"STORES? A=NO"
PROMPT
GTO 10
♦LBL A
2
ST- 00
♦LBL 10
"VSTALL="
ARCL 00
PROMPT
RCL 00
1.09
*
"VWRNG="
ARCL X
PROMPT
RCL 00
1.18
*
"VMINAPP="
ARCL X
PROMPT
RCL 00
1.28
*
"VOPTAPP="
ARCL X
PROMPT
GTO "LAA"
END
```

RS - MAXIMUM REFUSAL SPEED

1. EQUATIONS

$V_r = q - G(0.2222 + 0.0028q)$

$q = s + V_W(0.815 + 0.0015s)$

$s = 20.2262 + 0.998657a + 0.012087 + 0.0012332aL$

$+ 0.21508a^2 - 5.8018\times10^{-6}L^2$

$a = 10.396 - 0.059933W - 0.345833H - 0.020611T$

V_r = refusal speed [KCAS]

G = runway slope gradient (+uphill/-downhill) [percent]

V_W = wind component (+headwind/-tailwind) [knots]

W = aircraft gross weight [pounds/1000]

h = runway pressure altitude [pounds/1000]

T = runway temperature [degrees Fahrenheit]

2. FLOWCHART

See following page.

4. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS

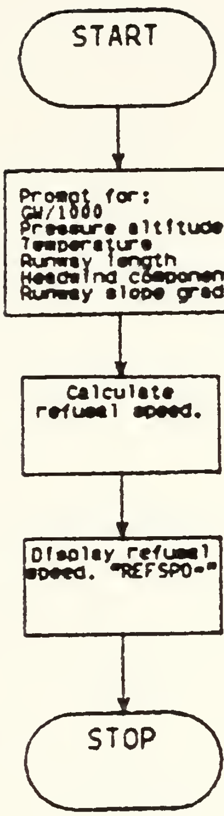
a. Flags used: none.

b. Data storage registers.

Register:	Contents:
R00	Intermediate variable (a)
R01	Runway length (L)
R02	Intermediate variable (s)

c. Program storage requirement is 33 registers, 230 bytes.

RS


START
Prompt for:
GW/1000
Pressure altitude
Temperature
Runway length
Headwind component
Runway slope gradient
Calculate
refuel speed.
Display refuel
speed. "REFSPD="
STOP

5. PROGRAM LISTING

```
 01♦LBL "RS"
 02 FIX 0
 03 10.3955
 04 ENTER↑
 05 "GW*1000
?"
 06 PROMPT
 07 .0599333
 08 *
 09 -
 10 "P.ALT:
FT?"
 11 PROMPT
 12 .345833
E-3
 13 *
 14 -
 15 "TEMP: F
?"
 16 PROMPT
 17 .0206108
 18 *
 19 -
 20 STO 00
 21 X↑2
 22 .215078
 23 *
 24 20.2262
 25 +
 26 "RWY LT:
 FT?"
 27 PROMPT
 28 STO 01
 29 .0120871
 30 *
 31 +
 32 RCL 00
 33 RCL 01
 34 *
 35 .0012332
2
 36 *
 37 +
 38 RCL 01
 39 X↑2
 40 .580182
E-6
 41 *
 42 -
 43 RCL 00
 44 .998257
 45 *
 46 +
 47 STO 02
 48 .0015
 49 *
 50 .815
 51 +
 52 "+HW/-TW
: KTS?"
 53 PROMPT
 54 *
 55 ST+ 02
 56 RCL 02
 57 .0028
 58 *
 59 .2222
 60 +
 61 CHS
 62 "RWY GRA
D?"
 63 PROMPT
 64 *
 65 RCL 02
 66 +
 67 "REFSPD:
"
 68 ARCL X
 69 AVIEW
 70 .END.
```

TANK - TANKER MISSION PROFILE - KA-6D

1. EQUATIONS

   a. Low holding.

   $$G_L = 0.98755Q - 4.9875t + 0.92422t^2 - 0.034546t^2Q - 4.7595$$

   b. High holding.

   $$G_H = 0.97560Q - 4.0873t + 0.60452t^2 - 0.025812t^2Q - 4.6476$$

   G = give away fuel [pounds/1000]

   Q = fuel onboard [pounds/1000]

   t = time until recovery [hours]

2. FLOWCHART

   See following page.

3. PROGRAMS AND SUBROUTINES USED

   None.

4. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS

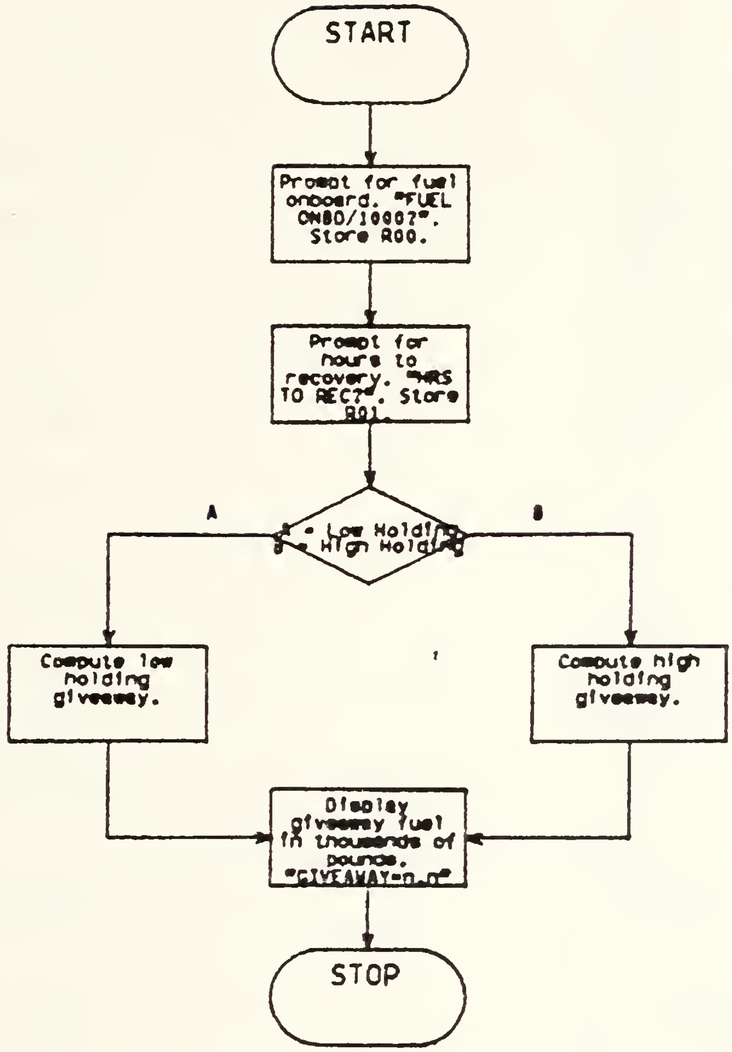
a. Flags used: none.

b. Data storage registers.

Register:	Contents:
R00	Fuel onboard (Q)
R01	Hours until recovery (t)

c. Program storage requirement is 25 registers, 174 bytes.

TANK


START
Prompt for fuel onboard. "FUEL ONBD/1000?". Store R00.
Prompt for hours to recovery. "HRS TO REC?". Store R01.
A
B
A = Low Holding
B = High Holding
Compute low holding giveaway.
Compute high holding giveaway.
Display giveaway fuel in thousands of pounds. "GIVEAWAY=n.n"
STOP

5. PROGRAM LISTING

```
 01◆LBL "TAN
K"
 02 FIX 1
 03 "FUEL ON
BD=?"
 04 PROMPT
 05 STO 00
 06 "HRS TO
REC?"
 07 PROMPT
 08 STO 01
 09 "A=LOW,
B=HIGH"
 10 PROMPT
 11◆LBL A
 12 X↑2
 13 .924222
 14 *
 15 RCL 01
 16 X↑2
 17 RCL 00
 18 *
 19 .0345456
 20 *
 21 -
 22 RCL 01
 23 4.98754
 24 *
 25 -
 26 RCL 00
 27 .987547
 28 *
 29 +
 30 4.75948
 31 -
 32 GTO 00
 33◆LBL B
 34 X↑2
 35 .604523
 36 *
 37 RCL 01
 38 X↑2
 39 RCL 00
 40 *
 41 .0258123
 42 *
 43 -
 44 RCL 01
 45 4.08726
 46 *
 47 -
 48 RCL 00
 49 .975598
 50 *
 51 +
 52 4.64756
 53 -
 54◆LBL 00
 55 "GIVEAWA
Y:"
 56 ARCL X
 57 AVIEW
 58 .END.
```

TO - NORMAL TAKE-OFF DISTANCE AND LINE SPEED CHECK

1. EQUATIONS

a. Take-off distance and speed.

$$V_2 = 21.41W^{0.4854}$$

$$K_t = 3.72x10^{4}W^{2.45}$$

$$K_a = 0.52399K_t + 5.2425x10^{-3}T + 3.0246x10^{-5}T\,K_t^2 + 9.5067x10^{-5}TK_t^2 - 3.8133x10^{-5}T^2 - 8.1735x10^{-4}K_t^3 - 0.067364$$

$$K_w = 0.035628 + 1.0106x10^{-4}A + 0.98964K_a - 8.8825x10^{-7}A^2 + 1.1121x10^{-6}A^2K_a + 1.1797x10^{-5}AK_a^2$$

$$K_g = K_w - (0.005 + 0.01K_w)W$$

$$D = K_g(1 + 0.03333G), \qquad (0 < K_g < 4.5)$$

$$D = K_g + G(0.06667K_g - 0.1333), \qquad (K_g \geq 4.5)$$

where

V_2 = lift-off speed (KCAS)

W = take-off gross weight [pounds/1000]

K_t = Temperature curve baseline

K_a = Pressure altitude curve baseline

T = runway temperature [degrees Fahrenheit]

K_w = wind curve baseline

A = runway pressure altitude [ft]

K_g = runway gradient curve baseline

G = runway slope gradient (+uphill/-downhill) [percent]

V = axial wind component (+headwind/-tailwind) [knots]

D = take-off ground roll [ft/1000]

b. Line speed check.

$$K_g = D'/(1 + 0.03333G)$$

$$K_w = (K_g + 0.005V)/(1 - 0.01V)$$

$$K_a = 1.0613K_w - 7.48433x10^{-4}A + 2.9436x10^{-7}A^2K_w - 8.7916x10^{-3}K_w^2 - 8.6058x10^{-5}AK_w - 0.08128$$

$$K_t = 0.32038 + 1.8396K_a - 0.016751T - 1.7559x10^{-3}TK_a^2 + 6.3515x10^{-5}T^2 + 0.014191K_a^3$$

$$L = 82.786 + 62.680K_t - 1.5818W - 6.4844K_t^2 + 0.015037W^2 - 0.65919K\ W + 0.088812K_t^2W$$

D' = line speed distance [feet/1000]

L = line speed [KCAS]

c. Warnings.

If $K_w \geqslant 7.5 + 6.25X10^{-6}A$, take-off is not recommended.

If $K_w \geqslant 9.0 + 1.0x10^{-5}A$, take-off is unsafe.

2. PROGRAMS AND SUBROUTINES USED

None.

3. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE REQUIREMENTS

a. Flags used: none.

b. Data storage registers.

Register:	Contents:
R00	Gross weight (W)
R01	K_t
R02	Runway temperature (T)

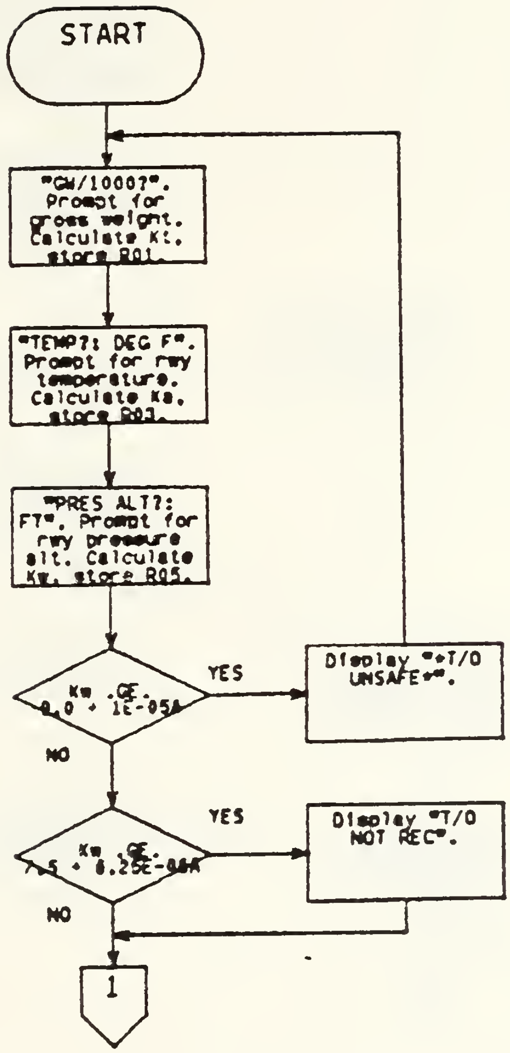
Register:	Contents:
R03	K_a
R04	Pressure altitude (A)
R05	K_w
R06	K_g
R07	Runway slope gradient (G)
R08	Headwind/tailwind (V)

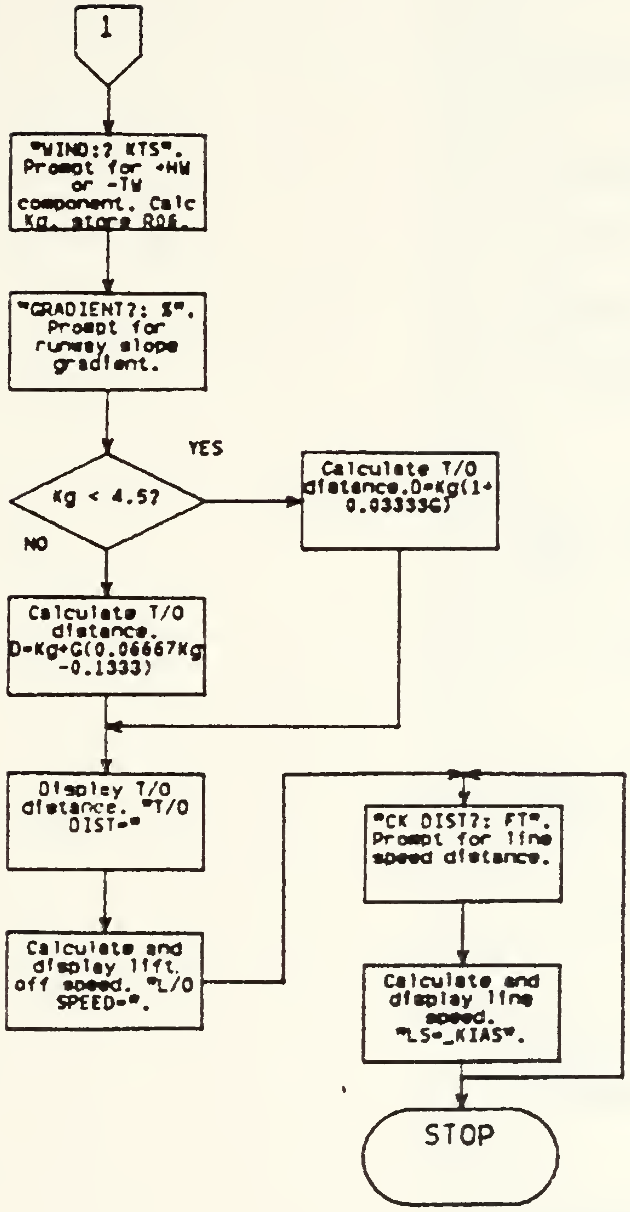
c. Program storage requirement is 105 registers, 733 bytes.

4. FLOWCHART

See following page.

TO


START
"GW/1000?". Prompt for gross weight. Calculate Kt, store R01.
"TEMP?: DEG F". Prompt for rwy temperature. Calculate Ka, store R03.
"PRES ALT?: FT". Prompt for rwy pressure alt. Calculate Kw, store R05.
Kw .GE. 9.0 + 1E-05A
YES
NO
Display "*T/O UNSAFE*".
Kw .GE. 7.5 + 8.25E-05A
YES
NO
Display "T/O NOT REC".
1


1
"WIND:? KTS". Prompt for +HW or -TW component. Calc Kg, store R06.
"GRADIENT?: %". Prompt for runway slope gradient.
Kg < 4.5?
YES
NO
Calculate T/O distance. D=Kg(1+0.03333G)
Calculate T/O distance. D=Kg+G(0.06667Kg -0.1333)
Display T/O distance. "T/O DIST="
Calculate and display lift off speed. "L/O SPEED=".
"CK DIST?: FT". Prompt for line speed distance.
Calculate and display line speed. "LS=_KIAS".
STOP

5. PROGRAM LISTING

```
 01♦LBL "TO"
 02 FIX 0
 03 "GW/1000
?"
 04 PROMPT
 05 STO 00
 06 2.45
 07 Y↑X
 08 3.72 E-4
 09 *
 10 STO 01
 11 "TEMP?:
DEG F?"
 12 PROMPT
 13 STO 02
 14 5.24248
E-3
 15 *
 16 RCL 01
 17 .523991
 18 *
 19 +
 20 RCL 01
 21 RCL 02
 22 X↑2
 23 *
 24 3.02457
E-5
 25 *
 26 +
 27 RCL 01
 28 X↑2
 29 RCL 02
 30 *
 31 9.50674
E-5
 32 *
 33 +
 34 RCL 02
 35 X↑2
 36 3.81333
E-5
 37 *
 38 -
 39 RCL 01
 40 3
 41 Y↑X
 42 8.1734 E
-4
 43 *
 44 -
 45 .0673642
 46 -
 47 STO 03
 48 .989643
 49 *
 50 "PRES AL
T?: FT"
 51 PROMPT
 52 STO 04
 53 1.01058
E-4
 54 *
 55 +
 56 RCL 04
 57 RCL 03
 58 X↑2
 59 *
 60 1.17971
E-5
 61 *
 62 +
 63 RCL 04
 64 X↑2
 65 RCL 03
 66 *
 67 .111214
E-7
 68 *
 69 +
 70 RCL 04
 71 X↑2
 72 .888251
E-8
 73 *
 74 -
 75 .0356282
 76 +
 77 STO 05
 78 9
 79 -
 80 RCL 04
 81 1 E-5
 82 *
```

```
 83 -
 84 X>0?
 85 GTO 30
 86 RCL 05
 87 7.5
 88 -
 89 RCL 04
 90 6.25 E-6
 91 *
 92 -
 93 X>0?
 94 GTO 40
 95 GTO 50
 96♦LBL 30
 97 "*T/O UN
SAFE*"
 98 AVIEW
 99 STOP
100 GTO "TO"
101♦LBL 40
102 "T/O NOT
 REC"
103 AVIEW
104 STOP
105 GTO 50
106♦LBL 50
107 RCL 05
108 .01
109 *
110 .005
111 +
112 "WIND?:
KTS"
113 PROMPT
114 STO 08
115 *
116 CHS
117 RCL 05
118 +
119 STO 06
120 "GRADIEN
T?: %"
121 PROMPT
122 STO 07
123 RCL 06
124 4.5
125 -
126 X<0?
127 GTO 10
128 RCL 06
129 .06676
130 *
131 .13333
132 -
133 RCL 07
134 *
135 GTO 20
136♦LBL 10
137 RCL 07
138 RCL 06
139 *
140 .03333
141 *
142♦LBL 20
143 RCL 06
144 +
145 100
146 *
147 RND
148 10
149 *
150 "T/O DIS
T="
151 ARCL X
152 AVIEW
153 STOP
154 RCL 00
155 .4854
156 Y↑X
157 21.41
158 *
159 "L/O SPD
="
160 ARCL X
161 AVIEW
162 STOP
163♦LBL 60
164 "CK DIST
?: FT"
165 PROMPT
166 1000
167 /
168 RCL 07
169 .033333
170 *
171 1
172 +
173 /
174 RCL 08
175 .005
176 *
177 +
```

```
178 1
179 ENTER↑
180 RCL 08
181 .01
182 *
183 -
184 /
185 STO 05
186 1.06129
187 *
188 RCL 04
189 .748427
E-5
190 *
191 -
192 RCL 04
193 X↑2
194 RCL 05
195 *
196 .294358
E-8
197 *
198 +
199 RCL 05
200 X↑2
201 8.79159
E-3
202 *
203 -
204 RCL 04
205 RCL 05
206 *
207 8.60575
E-5
208 *
209 -
210 .081277
211 -
212 STO 03
213 1.83958
214 *
215 .32038
216 +
217 RCL 02
218 .0167512
219 *
220 -
221 RCL 03
222 X↑2
223 RCL 02
224 *
225 1.75589
E-3
226 *
227 -
228 RCL 02
229 X↑2
230 6.35152
E-5
231 *
232 +
233 RCL 03
234 3
235 Y↑X
236 .0141913
237 *
238 +
239 STO 01
240 62.6795
241 *
242 82.7861
243 +
244 RCL 00
245 1.58175
246 *
247 -
248 RCL 01
249 X↑2
250 6.48441
251 *
252 -
253 RCL 00
254 X↑2
255 .0150366
256 *
257 +
258 RCL 00
259 RCL 01
260 *
261 .659185
262 *
263 -
264 RCL 01
265 X↑2
266 RCL 00
267 *
268 .0888122
269 *
270 +
271 "L/S="
272 ARCL X
273 "⊢ KIAS"
```

```
274 AVIEW
275 STOP
276 GTO 60
277 .END.
```

XWL - CROSSWIND TAKE-OFF/LANDING

1. EQUATIONS

$XWC = WV\sin|WD - RH|$

$HWC = WV\cos|WD - RH|$

$XWC < (HWC + 64.865)/3.243$

Note: This is the equation of the line which defines the RECOMMENDED/NOT RECOMMENDED regions on the NATOPS crosswind landing chart.

$MTAS = 3.243XWC + 15.135$

where

XWC = crosswind component [knots]

WV = wind velocity [knots]

WD = wind direction [degrees]

RH = runway heading [degrees]

HWC = headwind component [knots]

MTAS = minimum nose wheel liftoff speed [KTAS]

2. PROGRAMS AND SUBROUTINES USED

None.

3. FLAGS, DATA STORAGE REGISTERS AND PROGRAM STORAGE RQUIREMENTS

a. Flags used: none.

b. Data storage registers.

Register:	Contents:
R00	Runway heading (RH)
R01	Wind direction (WD)

Register:	Contents:
R02	Wind velocity (WV)
R03	|WD - RH|
R04	Crosswind component (XWC)
R05	Headwind component (HWC)

c. Program storage requirement is 22 registers, 152 bytes.

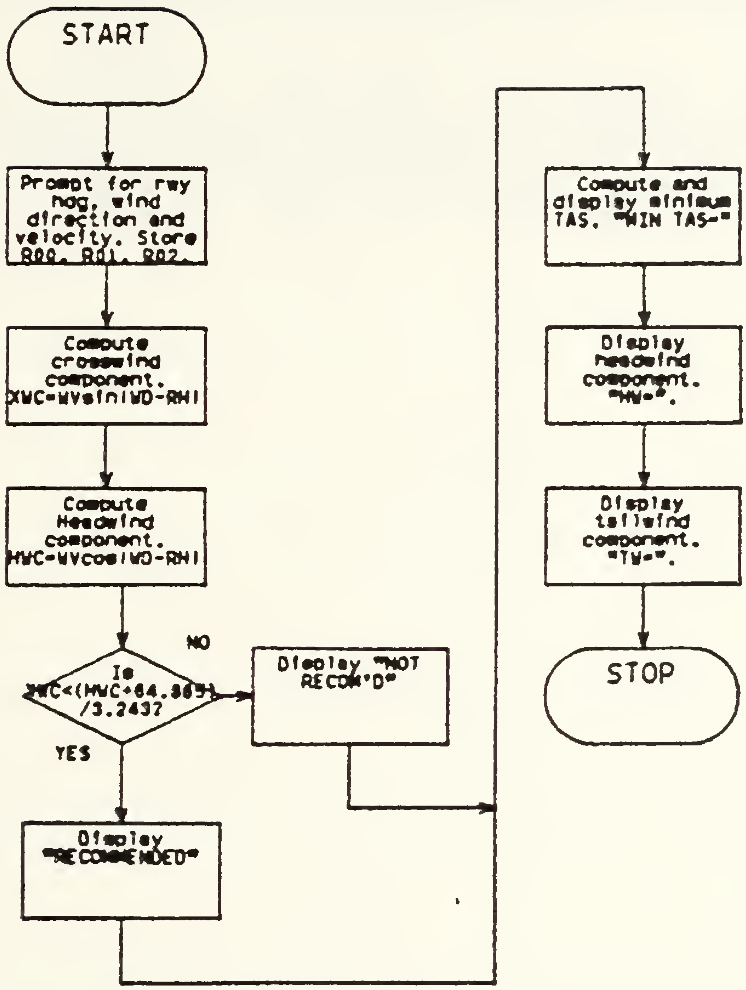
4. FLOWCHART

See following page.

5. PROGRAM LISTING

```
01♦LBL "XWL
"
02 "RWY HDG
?"
03 PROMPT
04 STO 00
05 "WIND DI
R?"
06 PROMPT
07 STO 01
08 "WIND VE
L?"
09 PROMPT
10 STO 02
11 RCL 00
12 RCL 01
13 -
14 ABS
15 STO 03
16 SIN
17 RCL 02
18 *
19 STO 04
20 RCL 03
21 COS
22 RCL 02
23 *
24 STO 05
25 64.865
26 +
27 3.243
28 /
29 RCL 04
30 X>Y?
31 GTO 01
32 "RECOMME
NDED"
33 PROMPT
34 GTO 02
35♦LBL 01
36 "NOT REC
OM,D"
37 PROMPT
38♦LBL 02
39 RCL 04
40 3.243
41 *
42 15.135
43 +
44 FIX 0
45 "MIN TAS
="
46 ARCL X
47 PROMPT
48 "HW="
49 ARCL 05
50 PROMPT
51 "XW="
52 ARCL 04
53 PROMPT
54 GTO "XWL
"
55 END
```

XWL


START
Prompt for rwy hdg, wind direction and velocity. Store R00, R01, R02.
Compute crosswind component. XWC=WVsin(WD-RH)
Compute Headwind component. HWC=WVcos(WD-RH)
Is XWC<(HWC+64.885)/3.2437
NO
YES
Display "NOT RECOM'D"
Display "RECOMMENDED"
Compute and display minimum TAS. "MIN TAS="
Display headwind component. "HW=".
Display tailwind component. "TW=".
STOP

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Thesis
H223 Hargrave
c.1 Development of the
A-6E/A-6E TRAM/KA-6D
NATOPS Calculator Aided
Performance Planning
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